To the Graduate Council:

I am submitting herewith a dissertation written by Loren D. Lutes, entitled "The Relationship Between Piagetian Logical Operations Level and Achievement in Intermediate Science Curriculum Study." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Education, with a major in Curriculum and Instruction.

Woodrow W. Wyatt, Major Professor

We have read this dissertation
and recommend its acceptance:

Accepted for the Council:

Vice Chancellor
Graduate Studies and Research

THE RELATIONSHIP BETWEEN PIAGETIAN LOGICAL OPERATIONS LEVEL AND ACHIEVEMENT IN INTERMEDIATE SCIENCE CURRICULUM STUDY

A Dissertation

Presented for the

Doctor of Education

Degree

The University of Tennessee, Knoxville

Loren D. Lutes

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DEDICATION

This dissertation is dedicated in loving appreciation to my wife, Vera, and to our children, Joel, Christine and Phillip.

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ABSTRACT

This study was concerned with logical operations which occur in the concrete and formal operational stages as described by Swiss epistemologist Jean Piaget. The relationship between Piagetian logical operation levels and achievement in ISCS was found to be significant. Student logical operation levels were determined using a paper and pencil test.

Ninth grade students in the Wichita public schools were tested for logical operation levels, ISCS achievement, and their fifth and sixth grade science background was examined. Fifth and sixth grade background was not found to be a significant factor in logical level or ISCS achievement. The students who scored higher on the logical operations test were significantly more successful on the ISCS achievement test. Less than one-fourth of the students tested were formal operational.

The study indicated that science curricula should be designed to help elementary students begin to think more logically. Also, junior high students at different logical levels should have curricula suited to their needs.

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CHAPTER I

INTRODUCTION

Several theories have been developed to explain intellectual development. Jean Piaget, a Swiss epistemologist who has been studying children for 50 years, has developed what is generally regarded the best picture of how intellective development takes place. He asks, how does the child acquire knowledge, and what happens to mental processes when he does? To Piaget, the development of intelligence means the development of logical thinking, man's highest attribute.[1]

For Piaget the development of intelligence goes through stages from birth to maturity. The distinct stages identified by Piaget are the sensory-motor stage (ages 0-2 years), the stage of preoperational thought (ages 2-7 years), the concrete-operational stage (ages 7-11 years), and the stage of formal operations (11 years and over). The stages are of invariant sequence, and cumulative.[2]

This study is concerned with logical operations which occur in the concrete and formal operational stages. Piaget defines an operation as an intellectual activity that can return to its starting point and can be integrated with other actions.[3]

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[1]Celia Stendler Lavatelli, Walter J. Moore, and Theodore Kaltsounis, Elementary School Curriculum (New York: Holt, Rinehart and Winston, Inc., 1965) pp. 44-46.

[2]Ellis Evans, "The Piagetian Mystique," Contemporary Influences in Early Childhood Education (2d ed., New York: Holt, Rinehart and Winston, 1975) p. 195.

[3]Barbel Inhelder and Jean Piaget, The Growth of Logical Thinking from Childhood to Adolescence (New York: Basic Books, Inc., 1958) p. 245.

> An operation is thus the essence of knowledge: it is an interiorized action. . . . But, in addition, it is a reversible action; that is, it can take place in both directions, for instance, adding or subtracting, joining or separating. . . . Above all an operation is never isolated. It is always linked to other operations, and as a result it is always a part of a total structure. . . . These operational structures are what seem to me to constitute the basis of knowledge, the natural psychological reality, in terms of which we must understand the development of knowledge.[4]

Mental acts of reasoning performed on real or concrete objects and events are called concrete operations.[5] ". . . I call these concrete operations because they operate on objects, and not yet on verbally expressed hypotheses."[6]

"Finally, in the fourth stage, these operations are surpassed as the child reaches the level of what I call formal or hypothetic-deductive operations. . . ."[7] Operational thought systems become integrated, forming structures which allow hypotheses to be generated and logical conclusions deduced.[8]

The ability of secondary science students to apply formal operations in processing science information appears to be associated with high science achievement. "A Highly significant relationship exists between operations classifications and level of science achievement for each sex."[9]

Other researchers have found that for science students in grades 8 and 9, those at the formal operational level received significantly

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[4] Jean Piaget, "Cognitive Development in Children," Journal of Research in Science Teaching, 2: 176-186, 1964.

[5] Evans, p. 196. [6] Piaget, p. 177. [7] Ibid. [8] Evans, p. 196.

[9] T. W. Field and A. J. Cropley, "Cognitive Style and Science Achievement," Journal of Research in Science Teaching, 6: 5-10, March, 1969.

higher grades in science than non-formal operational students. Thus, scholastic success of these adolescents is significantly related to formal thinking ability.[10]

Students who study certain inquiry science curricula significantly improve their ability for logical thinking over controls. Inquiry physical science curricula were more effective in grades 8 and 9 in enhancing the development of formal operations than the controls.[11]

The Intermediate Science Curriculum Study (ISCS) Levels I, II, and III constitute an inquiry science program for grades 7, 8, and 9. It is an integrated program with an individualized format.[12] The ISCS student materials were prepared in consideration of Piaget's work, as well as that of other learning theorists.[13]

> Using the logic and vast experience of Piaget and other learning theorists, the ISCS writers have tried to begin with what the student is capable of doing, and then expand the student's experiences through concrete activities. They considered the student through the eyes of the scientist.[14]

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[10] Steve Sayre and Daniel W. Ball, "Piagetian Cognitive Development and Achievement in Science," Journal of Research in Science Teaching, 12 (2): 165-174.

[11] Faith Elizabeth Friot, "The Relationship Between an Inquiry Teaching Approach and Intellectual Development" (unpublished Ph.D. dissertation, The University of Oklahoma, Norman, 1970), p. 6.

[12] D. W. McCurdy, "An Analysis of Qualities of Self-Directedness as related to Selected Characteristics of ISCS Students," Science Education, 59 (1): 5-12, May, 1975, p. 5.

[13] Ernest Burkman, ed., "Piaget's Stages and Their Relevance to Instruction," in Rationale for Individualization (Morristown, New Jersey: Silver Burdett Company, 1975) E. 3-2, p. 2.

[14] Ibid.

Tests conducted to determine performance of ISCS students on certain Piagetian type conservation tasks reveal that Level III students did not perform significantly different from non-ISCS students on the conservation tasks. However, there was a significant difference in both groups in the performance of high and low ability students.[15] Another study with Level I ISCS students failed to detect formal operational thinking.[16]

The Elementary Science Study (ESS) has as a key purpose that of making science a meaningful and enjoyable experience. Ways of learning which involve the child directly with concrete experiences are essential for science instruction. The ESS problems are situations in which reasoning ability is called for.[17] ESS is an activity-based, inquiry-oriented program that gives high priority to activities that stimulate interest and curiosity.[18] The units are designed to establish a setting in which children become involved in activities of their own choice and design. The developers place greater importance on the

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[15] Thomas Gilbert Teates, "A Comparison of Performance of ISCS and Non-ISCS Ninth-Grade Science Students on Several Piaget-Type Tasks" (unpublished Ph.D. dissertation, The Florida State University, Tallahassee, 1970).

[16] James P. Hale, "An Investigation of Two Operational Schemata in Adolescents Enrolled in the ISCS Classrooms of Three Selected Teachers" (unpublished Ph.D. dissertation, The University of Iowa, Iowa City, 1972).

[17] David P. Butts, Teaching Science in the Elementary School (New York, The Free Press, 1973).

[18] Ronald Simpson, "A Comparison of Biologic Content in Three Elementary School Science Curriculum Projects: ESS, S-APA, SCIS," The American Biology Teacher, 36 (6): 340-343, September, 1974.

investigative nature of science than on the content of science.[19]

A. STATEMENT OF THE PROBLEM

The purpose of the study was to analyze the relationships between logical operation levels (LOL) and achievement of ISCS students. The influence of completing ESS in grades 5 and 6 on ISCS achievement was compared with LOL effects.

B. HYPOTHESES

1. Students who have had an inquiry science background (two years of ESS instruction in grades 5 and 6) are not more logical than those with a traditional science background.

2. The achievement of students in ISCS is not significantly related to their LOL.

3. Students in the lower 27% on the ISCS Achievement Test do not differ significantly in LOL from those in the upper 27%.

4. Students who have an inquiry science background are not significantly higher achievers in ISCS than those with traditional elementary science backgrounds.

5. The inquiry science background will not be significantly more important to the formal operational students than to the concrete operational students.

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[19]Ronald D. Anderson and others, Developing Childrens Thinking Through Science (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1970), pp. 186-188.

C. IMPORTANCE OF THE STUDY

There has been a resurgence of interest in the work of Piaget, but the majority of studies use elementary school pupils as subjects. Few studies have been done in which junior high students are used as subjects. According to Tisher, few researchers have used paper and pencil tests to determine intellectual development levels.[20]

> A review of the literature indicates a need to identify the relationships existing between scholastic success of adolescents enrolled in science courses and their cognitive stages of mental development. Little material has been published regarding adolescent scholastic success and cognitive development. Authorities suggest research into scholastic success and cognitive development. Authorities suggest research into scholastic success and cognitive developmental levels may improve science instruction in the public schools.[21]

"One of the major difficulties found in science education is the comprehension of science concepts that incorporate some logic."[22] ISCS involves the development of concepts through logical means. Hale found in studying Piagetian logic that some of the material in Level I ISCS is intellectually inappropriate.[23]

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[20] R. P. Tisher, "A Piagetian Questionnaire Applied to Pupils in a Secondary School," Child Development, 42: 1633-36, November, 1971.

[21] Daniel Wayne Ball and Steven Athol Sayre, "Relationships Between Student Piagetian Cognitive Development and Achievement in Science" (unpublished Doctoral dissertation, University of Northern Colorado, Greeley, 1972), p. 12.

[22] Ronald J. Raven, "Programming Piaget's Logical Operations for Science Inquiry and Concept Attainment," Journal of Research in Science Teaching, II: 251-261, March, 1974.

[23] Hale, p. 86.

The limited amount of published research involving inquiry junior high science students and IOL is not consistent. Also, these studies only consider one school year or less of the students' science background. The need exists to identify relationships betweeen IOL and long term inquiry science study. If a large group of students is to be involved in the study, then paper and pencil methods must be employed to determine IOL.

D. ASSUMPTIONS

1. Students performing in different logical operation levels are found in the sample used in this study.

2. Logical operation levels are determined with a paper and pencil test.

3. Success in ISCS can be determined using the Level II ISCS Achievement Test.

E. LIMITATIONS OF THE STUDY

1. The population was limited to Level III ISCS students enrolled in three schools.

2. The classification of students is limited to formal-operational or concrete operational levels, although, students may be somewhere along a continuum between these levels, conceivably pre-operational.

F. ORGANIZATION OF THE STUDY

Chapter I presented a description of the problem and its rationale. Chapter II presents a comprehensive review of the related literature. Chapter III presents the procedures for collecting data and its analysis.

Chapter IV contains the data and its analysis. Chapter V contains conclusions and discussion.

CHAPTER II

REVIEW OF RELATED LITERATURE

This chapter contains the review of literature which examined the Piagetian logical operations, and their various applications to science curricula and teaching. Since there are few studies on Piagetian logic involving junior high students,[1] the review included selected studies at the elementary and secondary levels. The determination of logical operation level (LOL) using paper and pencil tests was studied.

A. LOGICAL OPERATION LEVELS AND THEIR ASSESSMENT

Operations in the strict sense, include both the concrete and formal operational operative stages.[2] Compared to concrete thought, formal thought constitutes a new equilibrium.[3] At a given stage of mental development an individual can bring a group of operations to bear on a problem, but each stage is characterized by a different group of such operations.[4]

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[1] R. P. Tisher, "A Piagetian Questionnaire Applied to Pupils in a Secondary School," Child Development, 42: 1633-36, November, 1971, p. 1632.

[2] Hans G. Furth, Piaget and Knowledge: Theoretical Foundations (Englewood Cliffs: Prentice-Hall, Inc., 1969) p. 260-65.

[3] Barbel Inhelder and Jean Piaget, The Growth of Logical Thinking from Childhood to Adolescence (New York: Basic Books, Inc., 1958) p. 245.

[4] T. W. Field and A. J. Cropley, "Cognitive Style and Science Achievement," Journal of Research in Science Teaching, 6: 2-10, March, 1969, p. 2.

Concrete operations are characterized by reversibility of thinking action.[5] The thinking content of the child in the stage of concrete operations is concrete rather than abstract, responding to real situations. Mental operations include combining elements figuratively as well as literally.[6]

The first characteristic of formal operations is the shift from the real situation to the possible. Combinatorial analysis, making sure all possible variables and combinations of variables have been tested, can be employed instead of unsystematic trial and error.[7] The combinatorial analysis and application of the possible are apparent in the actualization of hypothetic-deductive reasoning.[8] Hypothetic-deductive or formal thinking relies on the role of possibility in the logical sense.[9]

"It is important to note that Piaget's methods of experimentation are not standardized; instead, he uses an interview technique known as the 'clinical method.'"[10] The interview involves various tasks

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[5] Furth, p. 63.

[6] Celia Stendler Lavatelli, Walter J. Moore, and Theodore Kaltsounis, Elementary School Curriculum (New York: Holt, Rinehart, and Winston, Inc., 1965) p. 45.

[7] Lavatelli, p. 46.

[8] Daniel Wayne Ball and Steven Athol Sayre, "Relationships Between Student Piagetian Cognitive Development and Achievement in Science" (unpublished Doctoral dissertation, University of Northern Colorado, Greeley, 1972), p. 14.

[9] Inhelder, p. 257.

[10] Ronald J. Raven, "Logical Operations," Science Education, 57: 377-385, March, 1973, p. 377.

being assigned to students. The interviewer uses their manipulation of materials and responses to questions about why they choose certain manipulations for solving the task to determine the student's operational level. Piaget and Inhelder[11] have described the tasks and clinical interviews in detail.

B. PAPER AND PENCIL DETERMINATION OF LOGICAL OPERATION LEVELS

It is difficult to determine the logical operation level (LOL) of large groups of students using the "clinical method," because the interview is individual. It has not been possible to assess the mental level of a particular class with much precision.[12]

Because of the relationship between Piaget's logical operations and concept acquisition, the construction of a paper and pencil instrument to assess operations appears fruitful. The design of instruments to assess LOL is still in its infancy.[13] There is a need to construct a Piagetian instrument to compare results with those from a conversation-interview, clinical method.[14]

"A first step in the development, validation, and use of a Piagetian questionnaire was taken several years ago in Australia."[15] The Understanding in Science Test[16] (UIST) is a paper and pencil instrument

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[11]Inhelder, pp. 3-244.

[12]Michael Shayer and David Wharry, "Piaget in the Classroom Part I: Testing a Whole Class at the Same Time," School Science Review, 55, March, 1974, p. 447.

[13]Raven, p. 377. [14]Tisher, p. 1633. [15]Ibid.

[16]R. P. Tisher and L. G. Dale, Understanding in Science Test (Hawthorn, Victoria: Australian Council for Educational Research, 1975).

to assess LOL. It was developed from the Understanding in Science[17] questionnaire prepared by Tisher, and is administered to an entire class at one time and requires four equipment demonstrations. This questionnaire had a 77% agreement in classification between the interview and questionnaire techniques for students ages 12 to 16 years. Students were classified as either concrete or formal operational with 37% of the students age 13 years 5 months to 14 years 9 months found to be formal operational.[18]

Another study of students with a mean age of seventeen years was completed using this same questionnaire. These 178 high school students were classified at three levels: concrete, formal and late formal operations.[19] "High science achievement appears to be associated with the ability to apply formal operations in processing science information."[20] The high achieving group was markedly superior to other groups on the questionnaire.[21]

Shayer and Wharry developed a method of testing a class which would reveal the level of Piagetian thinking of the student. Nine sub-stages were identified for each of seven tasks. Seven Piagetian tasks were designed to be demonstrated to a whole class. Written questions were distributed to the students, read orally, then written answers were given by the students.[22] Validity and correlation were not established.

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[17]Richard P. Tisher, "The development of Some Science Concepts: A Replication of Piagets Studies" (unpublished B.A. (Hons.) thesis, University of New England, Armidale, New South Wales, Australia, 1962).

[18]Tisher, p. 1635. [19]Field, p. 4. [20]Field, p. 5. [21]Ibid.

[22] Shayer and Wharry, p. 447.

Another paper and pencil test was developed by Longeot.[23,24] Sheehan used a form of the Longeot test to determine the LOL of students ages 12.5 to 13.5. He determined that 43% of the 189 students were formal, and found that both concrete and formal operational students find concrete instruction more effective.[25]

Lawson and Blake used Sheehan's version of the Longeot test, along with Piagetian tasks to study the LOL of biology students with an average age of 15 years 5 months. There was a significant relationship between the two classifications with 43% of the students being concrete operational.[26]

The Longeot test was again used by Lawson in a study involving 62 students with average age of 15.2 years. Two Piagetian tasks were also used in this study of differences in LOL of male and female students. Considering the males and females combined, no difference was noted between the test and the tasks. Analyzing females alone it was found that somewhat different parameters were being measured by the test and tasks. Lawson found that the only difference between males

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[23]F. Longeot, "Un essai d'application de la psychologie genetique a la psychologid differentielle," Bulletin de l'Institut National D'Etude, 18 (3), 153-162, 1962.

[24]F. Longeot, "Analyse statistique de trois tests genetiques collectifs," Bulletin de l'Institut National D'Etude, 20 (4), 219-237, (1965).

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

[26]Anton E. Lawson, Anthony J. D. Blake, "Concrete and Formal Thinking Abilities in High School Biology Students as Measured by Three Separate Instruments," Journal of Research in Science Teaching, 13: 227-235, May, 1976.

and females on the Longeot test was in propositional logic. Males were found to be more formal than females.[27]

> If it is the case that male adolescents perform more formally than females then the shift in superiority seems to come about roughly towards the end of elementary school years and during the junior high school years.[28]

Another paper and pencil test has been developed by Raven, State University of New York. The Raven's Test of Logical Operations (RTLO) assesses the development of logical operations. It applies the problem solving rules described by Piaget, but is an extension of Piaget's research.[29] "The Raven's Test of Logical Operations (RTLO) has a format that poses problems in pictorial forms and verbally asks for solutions. The test uses a multiple choice format which is also pictorial in nature."[30]

The study of Raven and Polanski has as a purpose the extension of Piaget's work and current thinking about content comprehension.[31] The RTOL is employed as a LOL measure with reliability of 0.85.[32] The fourth and sixth graders tested showed their content comprehension to be significantly affected by logical operations.[33]

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[27]Anton E. Lawson, "Sex Difference in Concrete and Formal Reasoning Ability as Measured by Manipulative Tasks and Written Tasks," Science Education, 59 (3): 397-405, 1975, p. 403.

[28]Ibid. [29]Raven, p. 384.

[30]R. Raven and H. Polanski, "Relationships Among Piagets Logical Operations, Science Content Comprehension, Critical Thinking, and Creativity," Science Education 58 (4): 531-544, April, 1974, p. 534.

[31]Raven and Polanski, p. 531.

[32]Raven and Polanski, p. 536. [33]Raven and Polanski, p. 542.

The RTLO, which examines seven logical operations, was also tested on 424 students in grades 3, 5, 7 and 9. The reliability coefficient was found to be 0.79. The students in grades 7 and 9 attained significantly higher mean scores than those in grades 3 and 4.[34] "The results of the analysis of the RTLO have shown that it can be used to determine the developmental pattern of logical operations in children across grade levels."[35]

A prototype written test of cognitive development based on Piaget's model was developed by Gray under the sponsorship of the National Center for Educational Research and Development (DHEW/OE). The test development was only partially successful. Test items for exclusion and combination scales were determined to be successful. The results lend support to Piaget's contention of the invariant sequence of logical development for these logical structures. Proportional scale items were not successful due to rote learning techniques, and a different type of formal proportion item must be devised.[36]

Linn and Thier used the Cart Experiment to measure the logical thought of fifth (about age 13) and eighth graders. The Cart Experiment is a compensating variable task and was shown on silent 16mm film, then students wrote answers to written questions. The researchers found that fifth grade students studying SCIS Energy Sources scored higher than the controls and approached the scores of

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[34]Raven, p. 383. [35]Raven, p. 385.

[36]William M. Gray, Development of a Written Test Based Upon the Model of Piaget, Final Report, EDRS, ED 109-196, September, 1973.

the eighth graders. This measure is unable to distinguish formal thinkers.[37]

A whole class manipulation technique for determining LOL was devised by Rowell and Hoffmann. The class members were given relevant apparatus for two laboratory type Piagetian tasks. Instructions were written so that students did the manipulations, recorded their physical manipulations, and summarized their results. The researchers found that they could determine developmental levels of Australian high school students using the technique devised. They reported that the incidence of formal thinkers increased with chronological age.[38]

C. RESEARCH IMPLICATIONS

The Piagetian studies relevant to science education have been summarized by Chiappetta. He concludes that there is a relationship between cognitive development in adolescents and science achievement. Although only studies involving the clinical interview are included; less than 20% of seventh, eighth and ninth graders are formal operational.

Identifying the mental development of each child is an essential

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[37] Marcia C. Linn and Herbert D. Thier, "The Effect of Experiential Science on Development of Logical Thinking in Children," Journal of Research in Science Teaching 12 (1): 49-62, January, 1975.

[38] J. A. Rowell and P. J. Hoffmann, "Group Tests for Distinguishing Formal from Concrete Thinkers," Journal of Research in Science Teaching, 12 (2): 157-164, April, 1975.

[39] Eugene L. Chiappetta, "A Review of Piagetian Studies Relevant to Science Instruction at the Secondary and College Level," Science Education, 60 (2): 253-61, April, 1976.

component of a successful teaching solution.[40] The new inquiry science curricula assume formal operational thought, rather than attempting to develop it. The focus was to be upon understanding the basic logic and structure of science, and to make application by critical thinking and problem solving. The inappropriate assumption of formal thought has caused discouragement of proponents in the implementation of inquiry science.[41]

A random sample of three Oklahoma school populations were given Piagetian styled tasks, and were classified as concrete, post concrete, or formal operational. Lawson concluded from the study that over half of the tenth graders were concrete operational while a significant amount of the subject matter requires formal thought. This suggests that for over half of these students the subject matter is inappropriate.[42] "The possibility that the educational system itself is largely responsible for this low incidence of formal thinking seems to these investigators at the present time to be the most viable hypothesis."[43]

For several years Raven and associates have been researching the facilitation of logical operations in elementary and junior high students. The research implies that the use of logical operations in science instruction may enhance the acquisition and comprehension of

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[40]Rowell, p. 157.

[41]Lawrence Kohlberg and Carol Gilligan, "The Adolescent as a Philosopher: The Discovery of the Self in a Postconventional World," Daedalus 100: 1051-1086, 1971, p. 1082.

[42]Anton E. Lawson and John W. Renner, "A Quantitive Analysis of Responses to Piagetian Tasks and its Implications for Curriculum," Science Education, 58 (4): 454-559, 1974.

[43]Lawson and Renner, p. 558.

science concepts. Many children have difficulty understanding science concepts because they do not understand the logical operations involved. The logical organization of many concepts taught in school are too complex for the students' developmental level.[44] "The organization of the concepts needs to be matched to the developmental level of the students."[45] A major difficulty in science education is the comprehension of science concepts that incorporate some logic.[46]

The relationships between scholastic grades in science of junior and senior high students and their performance on formal operational tasks constituted the study of Ball and Sayre. Students from a Colorado school district comprised the sample of 419 students. A Piagetian Task Instrument (PTI) was constructed to determine if students' thinking was at the formal operational level. The PTI was administered by a trained interview team. Students were classified as either formal or non-formal operational. Eighth and ninth grade science students who demonstrated formal operational logic received significantly higher grades than non-formal students. The data showed 97.7% of junior high students receiving grades of D or F were non-formal, while 42.1% receiving A were formal. The same junior high students showed a 0.28 correlation between PTI performance and I.Q. No significant relationship was found between PTI performance and sex.[47]

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[44] Ronald J. Raven, "Programming Piaget's Logical Operations of Science Inquiry and Concept Attainment," Journal of Research in Science Teaching, 11: 251-261, March, 1974, p. 251.

[45] Raven, "Programming Piaget's Logical Operations," p. 256.

[46] Raven, "Programming Piaget's Logical Operations," p. 260.

[47] Ball, p. 1-85.

Implications identified were that:

> Secondary science instruction should be structured around the cognitive developmental level of the students involved. The results indicate the non-formal students are receiving lower grades because of their Piagetian cognitive developmental levels.[48]

A study by Friot evaluated the relationship between inquiry teaching and intellectual development. Tasks described by Inhelder and Piaget were used to evaluate changes in logical reasoning via pre and post interviews. Students enrolled in Time, Space, and Matter, Introductory Physical Science (IPS), and Earth Science Curriculum Project (ESCP) comprised the experimental group. Controls were enrolled in general science. The results showed IPS to be significantly more effective in enhancing the development of formal operations than the control. At grade 9 IPS was found to be significantly more effective for formal operations than ESCP. It was found that sex and I.Q. were not significantly related to gain in logical thinking ability.[49]

Field and Croply investigated "Cognitive Style and Science Achievement." Using the Understanding in Science Test developed by Tisher[50] to determine mental operation levels, they found that both boys and girls (178) at grades 10 and 11 had general science scores that correlated significantly with operations classification. Also a highly significant relationship was found between operations classifications and level of science achievement for each sex. High science achievement

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[48]Ball, p. 80.

[49]Faith Elizabeth Friot, "The Relationship Between an Inquiry Teaching Approach and Intellectual Development" (unpublished Ph.D. dissertation, The University of Oklahoma, Norman, 1970).

[50]Tisher, p. 1633.

appeared to be associated with their ability to apply formal operations to science. Significant superiority of boys in the development of formal operations was also found.[51]

The research reviewed indicates that the majority of junior and senior high school students function at the concrete operational level and not at the formal level in understanding science subject matter.[52]

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[51]Field, pp. 2-10. [52]Chiappetta, p. 259.

CHAPTER III

METHODS OF THE STUDY

This chapter contains information regarding the population and samples, the data that were collected, and the statistical analysis involved in interpreting the data.

A. THE POPULATION AND SAMPLE

The population consisted of 434 ninth grade students enrolled in Level III of the Intermediate Science Curriculum Study (ISCS) in the Wichita (Kansas) Public Schools, Unified School District #259. The criteria applied to the experimental population consisted of Level III students who had completed two years of ISCS and either two years of Elementary Science Study (ESS) or no ESS in grades 5 and 6. Students with one year of ESS, and less than two years of ISCS were eliminated from the sample. Tests were administered to all 434 students, and 282 students met the experimental criteria, and constitute the sample. The experimental population was enrolled in the ninth grade at Brook, Hadley or Wilbur Junior High School. Student's nearest age was from 13.5 to 15 years.

B. PROCEDURES USED IN DATA COLLECTION

The procedures in collecting data for the study involved administering the Understanding in Science Test (UIST) to each student in the population in September of 1976. The tests were administered and scored by the author, and students were classified as concrete-operational (C) or formal-operational (F), according to the guidelines developed by Tisher.[1] Students' raw scores were used as the dependent variable.

A background data sheet was developed, to determine the ISCS and ESS background of each student. (See Appendix I.) All students completed the data and were assigned to group A_2 if they had completed two years of ESS in grades 5 and 6, or to group A_1 if they had no ESS.

A Level II ISCS achievement test developed by ISCS was modified and used to determine ISCS achievement. The original test was modified to eliminate questions requiring more than one word answers. Only multiple choice or single word response items were included in the ISCS Achievement Test (IAT). This test was administered by the students' classroom teachers within a week of the original testing to determine logical operation levels (LOL). Test instructions were provided to each teacher. (See Appendix III.) The answer sheets were returned to the author for scoring. The score was number of right answers minus number of wrong answers on items with more than one correct answer. For items with only one correct answer no deduction was made for incorrect answers.

Students in Groups A_1 and A_2 were divided into four groups: A_1B_1, A_1B_2, A_2B_1, and A_2B_2. Students placed in A_1B_1 were those in group A_1 whose score on the IAT were in the lowest 27%. Those in A_1B_2 had scores in the highest 27% on their IAT from A_1. Similarly, in a group A_2, B_1 had the lowest 27% scores and B_2 the highest 27%.

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[1] R. P. Tisher and L. G. Dale, <u>Manual of Procedures and Theoretical Background for Understanding in Science Test</u> (Hawthorn, Victoria: Australian Council for Educational Research, 1975).

Finally the four groups were again divided according to LOL using their scores on the UIST. The highest 27% scores in each of the four groups were designated C_2 and the lowest 27% scores were designated C_1. Table I summarizes the eight treatment groups.

C. PROCEDURES FOR DATA ANALYSIS

Analysis of the data was accomplished using an analysis of variance (ANOVA) with a 2^3 factorial experiment. Since the treatments consisted of one level from each of the three factors, the experiment is described as a complete factorial with equal replications. This constitutes a fixed effect model, Model I, with factors Inquiry X Achievement X Level.[2]

The numerous applications of ANOVA constitute a very versatile collection of statistical aids in research. One of its strongest virtues is the ability to detect significant contributions from interactions of experimental variables. The ANOVA results in one or more F tests. The assumptions upon which an F test rests are the following: random sampling, homoscedasticity of variance, normally distributed population, and additive treatment effects. It should also be noted that F is rather insensitive to variation in shape of population distribution and to variations in variances of populations.[3]

The calculations were made with calculating formulas found in

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[2]Allen L. Edwards, Experimental Design in Psychological Research (New York: Holt, Rinehart and Winston, Inc., 1972), pp. 154-179.

[3]J. P. Guilford and Benjamin Fruchter, Fundamental Statistics in Psychology and Education (New York: McGraw-Hill Book Co., 1973), pp. 229-278.

TABLE I

THE EIGHT TREATMENT COMBINATIONS

Treatment	ESS	Achievement	Level
A_1 B_1 C_1	N	L	C
A_1 B_1 C_2	N	U	C
A_1 B_2 C_1	Y	L	C
A_1 B_2 C_2	Y	U	C
A_2 B_1 C_1	N	L	F
A_2 B_1 C_2	N	U	F
A_2 B_2 C_1	Y	L	F
A_2 B_2 C_2	Y	U	F

N: no ESS previous

Y: at least two years ESS previous

L: lower 27% on IAT

U: upper 27% on IAT

C: lower 27% on UIST

F: upper 27% on UIST

Source: Allen L. Edwards, Experimental Design in Psychological Research (New York: Holt, Rinehart, and Winston, Inc., 1972), p. 155.

Edwards.[4] Calculations were made using equations for equal and unequal n in each of the proper groups. A table of random numbers[5] was used to eliminate extra students in each group. Students were assigned numbers, the table entered randomly, and students whose numbers were selected were not included in the study. (See Appendix IV for complete selection procedures.)

The two-factor interaction effects were of particular interest. A X B enabled the experimenter to determine if students having an ESS background had higher achievement scores in ISCS. A X C determined if students with an ESS background think more logically. B X C showed if there was a difference between upper and lower ISCS achievement for concrete and formal students.

[4]Edwards, p. 460.

[5]Edwards, p. 158.

CHAPTER IV

DATA AND ANALYSIS

Chapter IV contains figures and tables showing the experimental results of the data collected. The analyses of the data using factorial experiments are also summarized.

A. DATA

The Understanding in Science Test (UIST) score was used as the criterion. The scores of the 434 students who took the test are shown in Figure I. Those students scoring from 1-10 points are classified by Tisher and Dale as early concrete. Those scoring from 11-19 are late concrete, from 20-26 are early formal, and from 27-34 are late formal.[1] Results of the UIST are summarized in Table II. It was observed by the classroom teachers and researcher that some of the students with scores of less than 10 were very poor readers.

The scores on the Intermediate Science Curriculum Study Achievement Test (IAT) are shown in Figure II. Only 430 students were present for this test. Scores for students who were not present for both tests were not used in the ANOVA.

The experimental sample for the ANOVA required students who had no Elementary Science Study (ESS) background or two years background in grades 5 and 6. Of the 434 students in the population 282 met this

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[1]R. P. Tisher and L. G. Dale, Manual of Procedures and Theoretical Background for Understanding in Science Test (Hawthorn, Victoria: Australian Council for Educational Research, 1975.

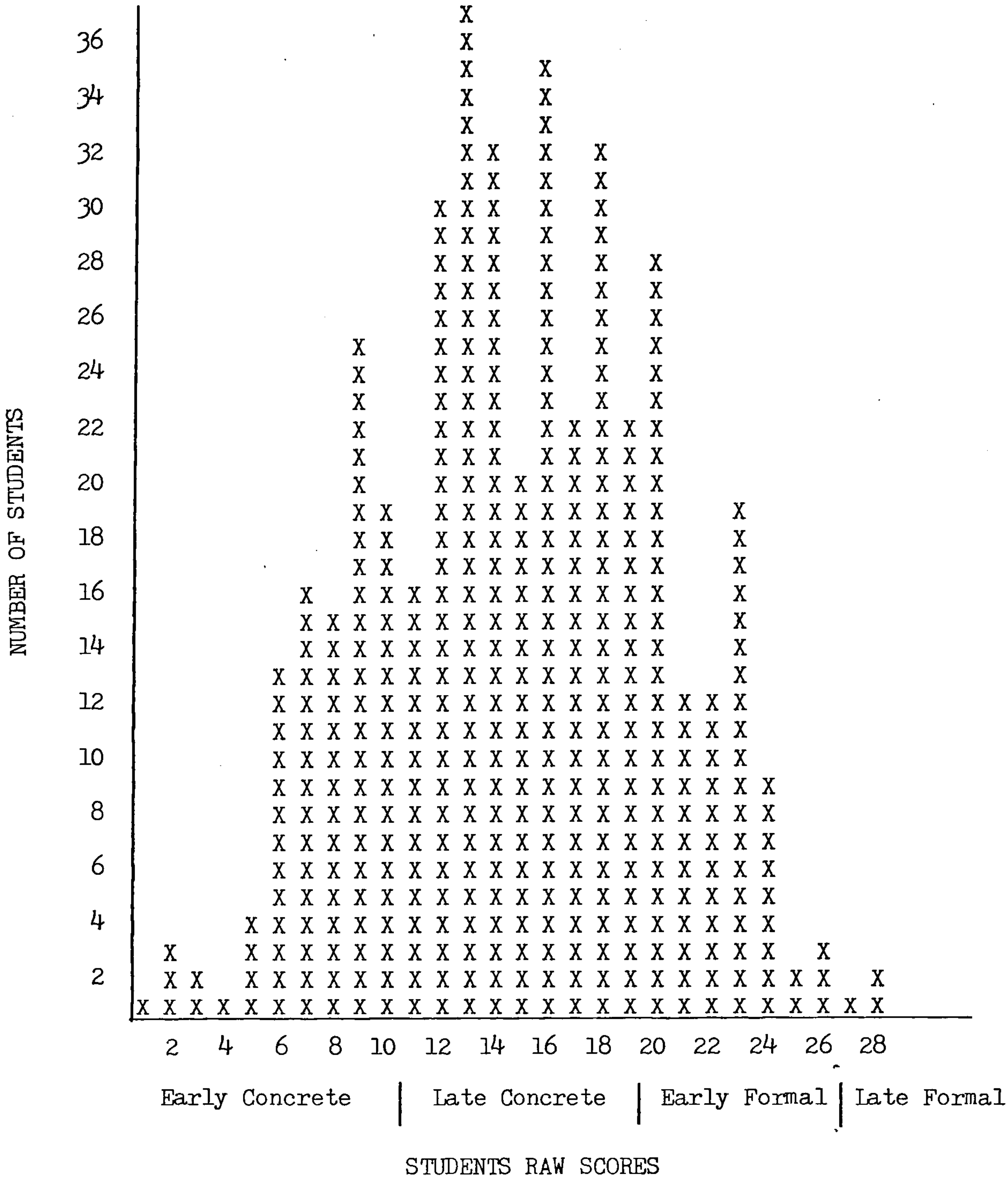

Figure I. Understanding in science test results showing logical levels.

TABLE II

UNDERSTANDING IN SCIENCE TEST RESULTS SHOWING PERCENTAGE OF STUDENTS IN EACH LOGICAL LEVEL

LOL	Range	Number of students	% of total
Early Concrete	1-10	99	22.8
Late Concrete	11-19	246	56.7
Early Formal	20-26	86	19.8
Late Formal	27-34	3	0.7
Total		434	100.0

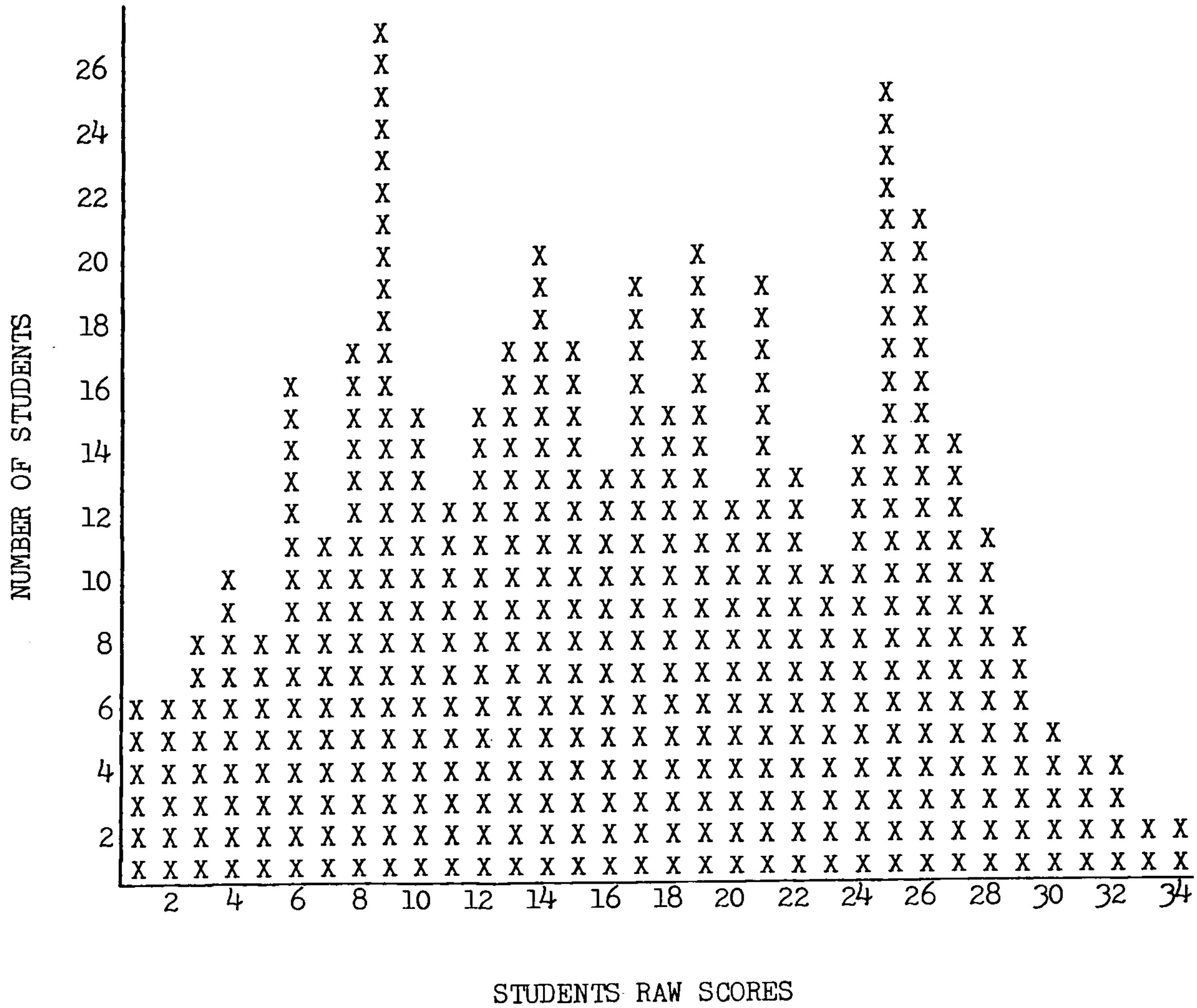

Figure II. Intermediate science curriculum study achievement test results.

criteria and took both tests. A total of 134 students with the ESS background were assigned to group A_2, and 148 students with no ESS were assigned to A_1.

B. DATA ANALYSIS

The ANOVA was a 2^3 factorial experiment. Two calculations were made for equal n, and one for unequal n. Concern over observed reading difficulties in the early concrete students led to their exclusion in two of the calculations.

A computer program to calculate the ANOVA for equal n was written in a fortran language.[2] The sample problem shown by Edwards[3] was used to verify the accuracy of the program.

The first calculation was made for equal n, using all students who met the criteria. Students were assigned to the appropriate cell, and randomly excluded until all cells had ten students. The data assigned to each cell was shown in Table III. Table IV shows the results of this calculation. Note that the three main effects were significant at the .01 level, and none of the interactions were significant.

It was observed during testing and confirmed by the classroom teachers that several of the students in the study had very poor reading abilities. The early concrete range contains some students who are early concrete in their thinking, some who may be pre-operational,

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[2]The author is indebted to his sister, Evelyn I. Eubank, for technical assistance in developing the computer program, and to Wichita State University for computer time.

[3]Allen L. Edwards, Experimental Design in Psychological Research (New York: Holt, Rinehart, and Winston, Inc., 1972), pp. 154-169.

TABLE III

CALCULATING DATA FOR EQUAL n
EARLY CONCRETE INCLUDED

$A_1B_1C_1$	$A_1B_1C_2$	$A_1B_2C_1$	$A_1B_2C_2$	$A_2B_1C_1$	$A_2B_1C_2$	$A_2B_2C_1$	$A_2B_2C_2$
7	14	16	20	9	14	17	23
7	13	5	20	9	14	17	23
7	17	10	25	9	14	16	23
6	16	6	23	2	20	16	23
6	16	15	26	5	21	9	24
5	15	15	22	8	26	14	24
2	15	15	25	6	17	16	24
5	15	13	21	8	19	14	27
6	12	6	23	2	16	14	26
6	12	15	24	6	15	14	28

TABLE IV

ANOVA FOR EQUAL n EARLY
CONCRETE INCLUDED

Source	SSD	df	MS	F
A	90.309	1	90.509	11.837**
B	1087.809	1	1087.809	142.585**
C	2111.513	1	2111.513	276.767**
AXB	1.012	1	1.012	0.133
AXC	1.012	1	1.012	0.133
EXC	1.512	1	1.512	0.198
AXBXC	19.018	1	19.018	2.493
Error	549.303	72	7.629	
(within				
Total	3861.488	79		

@.05 $*F_{1,\ 72} = 3.98$

@.01 $**F_{1,\ 72} = 7.00$

and some who may be formal thinkers that read poorly. To determine if this affected the results an ANOVA was calculated excluding those students with UIST scores in the early concrete range. Other procedures were the same as with the first calculation. The calculating data was summarized in Table V and the ANOVA results are shown in Table VI. Main effects B and C were still significant, but A was not. Interaction B X C was significant at the .05 level.

Another type of calculation using unequal n was made to determine if reducing the sample as was necessary for equal n changed the results of the ANOVA. Calculating formulas from Edwards[4] were again used in this calculation for unequal n. Table VII shows the data excluding early concrete data placed in the proper cells. The results of the ANOVA are shown in Table VIII. The main effects B and C were now significant at the .01 level.

[4]Edwards, pp. 217-220.

TABLE V

CALCULATING DATA FOR EQUAL n
EARLY CONCRETE EXCLUDED

$A_1B_1C_1$	$A_1B_1C_2$	$A_1B_2C_1$	$A_1B_2C_2$	$A_2B_1C_1$	$A_2B_1C_2$	$A_2B_2C_1$	$A_2B_2C_2$
12	16	16	20	13	21	18	28
12	17	15	22	13	26	14	26
12	18	16	24	11	20	16	27
12	18	15	23	12	19	14	24
12	19	16	23	12	17	17	24
12	19	15	25	11	18	14	24
13	19	15	26	12	19	14	23
13	22	13	23	12	17	17	23

TABLE VI

ANOVA FOR EQUAL n EARLY
CONCRETE EXCLUDED

Source	SSD	df	MS	F
A	8.266	1	8.266	2.846
B	268.141	1	268.141	92.334**
C	984.391	1	984.391	338.975**
AXB	1.266	1	1.266	0.436
AXC	6.981	1	6.891	2.373
BXC	13.141	1	13.141	4.525*
AXBXC	0.016	1	0.016	0.005
Error (within)	162.625	56	2.904	
Total	1444.734	63		

@.05 $*F_{1,\ 56} = 4.02$

@.01 $**F_{1,\ 56} = 7.12$

TABLE VII

CALCULATING DATA FOR UNEQUAL n
EARLY CONCRETE EXCLUDED

$A_1B_1C_1$	$A_1B_1C_2$	$A_1B_2C_1$	$A_1B_2C_2$	$A_2B_1C_1$	$A_2B_1C_2$	$A_2B_2C_1$	$A_2B_2C_2$
13	22	18	23	18	23	14	24
15	21	19	24	17	22	12	26
16	20	15	20	14	21	18	28
13	22	16	25	14	21	14	23
12	20	18	23	14	21	16	24
12	23	19	23	14	20	17	24
16	23	18	23	19	23	17	21
12		15		16	23	16	20
14		19		15	26	16	22
15		16		11		14	
12		17		13		16	
17		13		13		14	
19		15		13		14	
15		15		13		14	
18		17		12		18	
14		18		12		19	
11		16		15		18	
13		17		11		18	
19		17		12		19	
13		17		12		17	
18		16					
13		17					

TABLE VIII

ANOVA FOR UNEQUAL n EARLY CONCRETE EXCLUDED

Source	SSD	df	MS	F
A	0.01	1	0.01	0.0
B	6.30	1	6.30	17.6**
C	106.00	1	106.00	296.1**
AXB	0.00	1	0.00	0.0
AXC	0.81	1	0.81	2.3
BXC	0.30	1	0.30	0.8
AXBXC	-0.02	1	-0.02	-0.1
Error (within)	442.20	108	0.358	

@.05 $^{*}F_{1,\ 108} = 3.93$

@.01 $^{**}F_{1,\ 108} = 6.88$

CHAPTER V

CONCLUSIONS AND DISCUSSION

The conclusions of the study are described in this chapter. The hypotheses were tested and either rejected or not rejected. The educational implications were discussed and suggestions for further study were made.

A. CONCLUSIONS

The results of the Understanding in Science Test (UIST) have shown that 20.5% of the students completing the test are in the formal operational ranges. Because of the questionable reading skills observed there is some question about the classification of the students with scores 1-10. If these students are excluded then 25.6% would be formal. This range 20.5 to 25.6% is slightly higher than found by Chiappetta, but lower than those found by Tisher and Sheehan. The conclusion of this study was that no more than one-fourth of the sample ninth grade science students were formal operational.

Hypothesis #1 suggests that an Elementary Science Study (ESS) background will not affect the logical operation level (LOL) of students. It was tested by main effect A. When the early concrete students were included the F value was significant at the .01 level. In calculations where the early concrete students were excluded no significant difference was found. One possible conclusion was that any possible improvement in logical level was masked except when early concrete students were included. Another conclusion was that the students who had two years instruction in ESS were not more logical than those with traditional science instruction. The second conclusion was accepted and the hypothesis was not rejected.

Main effect B was a test of hypothesis #2 that Intermediate Science Curriculum Study (ISCS) achievement is not related to LOL, and hypothesis #3 that upper ISCS achievers do not differ in LOL from lower ISCS achievers. In all three calculations the F value was significant at the .01 level. The higher achieving students on the ISCS achievement were more logical than the lower achieving students. Hypotheses #2 and #3 were rejected since means of the upper and lower achievers differ significantly when averaged over E and Y, and F and C.

The premise of the study that differences in LOL can be determined was upheld in the significance at the .01 level of main effect C. In the third calculation of unequal n, $C_1 = 61.23$ and $C_2 = 90.35$; there is a significant difference of the means for C and F averaged over elementary background and achievement. The theory of Piaget is supported and the UIST is able to distinguish between logical levels.

The A X B interaction is a test of hypothesis #4, the elementary background will not affect ISCS achievement. The fact that this interaction mean square is not significant indicates that the difference between the elementary background for lower achieving students is not significantly different from the difference between the background means for upper achieving students. The mean squares for the three calculations being near zero indicates that difference in elementary background is independent of achievement. Whether a student has had ESS or not in grades 5 and 6 was not a good predictor of ISCS achievement. The null hypothesis was not rejected.

The interaction mean square A X C determined if elementary background was independent of LOL. The interaction mean square for background and logical level was not the same. There was a non-significant indication that LOL was not independent of background. This was similar to the non-significant indication for main effect A. The interaction mean square was not significant and hypothesis #1 was not rejected. Hypothesis #5 was also not rejected. Although, it may be possible that the ESS background was more important to the more formal students.

The B X C interaction was significant at the .05 level only for the equal n calculation where early concrete students were excluded. The lack of significance for the other calculations indicates that mean square difference from achievement is about the same for concrete and formal operational students. This may have indicated a lack of confounding in achievement and LOL.

B. EDUCATIONAL IMPLICATIONS

This study has shown that the ISCS achievement of the students tested is higher for the students who think more formally. It appears that the formal operational students would benefit from instruction designed for their operational level. Even more important, the concrete operational students need to have a science program mostly on the concrete level so that their achievement can be improved.

The fact that at least 75% of these ninth graders tested were not found to be formal operational should be of concern. Logical operations are a goal of science curricula, and continued program improvement is needed.

The study has shown that two years of ESS background in grades 5 and 6 produced no significant change in the students ISCS achievement or logical level. The ESS program or its teaching was no improvement over the traditional program in logical development or ISCS achievement. Science curricula need to be designed to help students become logical thinkers. Teachers need to be trained in the elements of logical thinking, so that they can identify the logical levels of students and adjust students educational programs accordingly. Paper and pencil tests, particularly the UIST, can and should be used to facilitate this identification.

C. SUGGESTIONS FOR FURTHER STUDY

Future studies of this type using paper and pencil tests of LOL should screen out very poor readers for interview testing. Even though they may be capable of logical thought, these poor readers score in the lowest level.

The portion of this study dealing with elementary background should be expanded to include other inquiry science programs. Comparative studies should be carried out, and studies covering several years of inquiry science should be made.

Other areas needing further study are those of other inquiry science programs and those at higher levels.

BIBLIOGRAPHY

BIBLIOGRAPHY

BOOKS

Anderson, Ronald D., and others. Developing Childrens Thinking Through Science. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1970.

Burkman, Ernest, ed. Rationale for Individualization. Morristown, New Jersey: Silver Burdett Company, 1975.

Butts, David P. Teaching Science in the Elementary School. New York: The Free Press, 1973.

Cochran, William G. Sampling Techniques. 2d. ed. New York: John Riley and Sons, Inc., 1963.

________, and Gertrude M. Cox. Experimental Designs. New York: John Riley and Sons, Inc., 1950.

Edwards, Allen L. Experimental Design in Psychological Research. 4th ed. New York: Holt, Rinehart and Winston, Inc., 1972.

Elkind, David. Children and Adolescents: Interpretive Essays on Jean Piaget. 2d. ed. New York: Oxford University Press, 1974.

Evans, E. Contemporary Influences in Early Childhood Education. 2d. ed. New York: Holt, Rinehart and Winston, 1975.

Furth, Hans G. Piaget and Knowledge Theoretical Foundations. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1969.

Gray, William M. Development of a Written Test Based Upon the Model of Piaget. Final Report. EDRS, Ed 109-196, September, 1973.

Guilford, J. P., and Benjamin Fruchter. Fundamental Statistics in Psychology and Education. 5th. ed. New York: McGraw-Hill Book Co., 1973.

Inhelder, Barbel, and Jean Piaget. The Growth of Logical Thinking from Childhood to Adolescence. New York: Basic Books, Inc., 1958.

Jacobson, Willard, and Allan Kondo. SCIS Elementary Science Sourcebook. Berkley: Science Curriculum Improvement Study, 1968.

Lavatelli, Celia Stendler, Walter J. Moore, and Theodore Kaltsounis. Elementary School Curriculum. New York: Holt, Rinehart, and Winston, Inc., 1965.

Renner, John W., and D. G. Stafford. Teaching Science in the Secondary School. New York: Harper and Row, 1972.

Tisher, Richard P., and L. G. Dale. Manual of Procedures and Theoretical Background for Understanding in Science Test. Hawthorn, Victoria: Australian Council for Educational Research, 1975.

________, and L. G. Dale. Understanding in Science Test. Hawthorn, Victoria: Australian Council for Educational Research, 1975.

PERIODICALS

Chiappetta, Eugene L. "A review of Piagetian Studies Relevant to Science Instruction at the Secondary and College Level." Science Education, 60 (2): 253-61, April, 1976.

Duckworth, Eleanor, and Jean Piaget. "Piaget Takes a Teachers Look," Learning, 22-26, October, 1973.

Field, T. W., and A. J. Cropley. "Cognitive Style and Science Achievement," Journal of Research in Science Teaching. 6:2-10, March, 1969.

Gray, William M. "Product and Process in Cognitive Development: Some Comparative Data on the Performance of School Age Children in Different Cultures," British Journal of Educational Psychology, 44 (3): 248-265, November, 1974.

Howe, Ann C. "Childhood Experiences in Science," Instructor, 84 (5): 58-59, January, 1975.

Johnson, C. C., and J. E. Sherman. "Effects of Behavioral Objectives on Student Achievement in ISCS," Science Education, 59 (2): 177-180, 1975.

Karplus, Elizabeth F., and Robert Karplus. "Intellectual Development Beyond Elementary School. I. Deductive Logic," School Science and Mathematics, 50: 398-406, May, 1970.

Kohlberg, Lawrence, and Carol Gilligan. "The Adolescent as a Philosopher: The Discovery of the Self in a Postconventional World," Daedalus, 100: 1051-1086, 1971.

Lawson, Anton E. "Sex Difference in Concrete and Formal Reasoning Ability as Measured by Manipulative Tasks and Written Tasks," Science Education, 59 (3): 397-405, 1975.

Lawson, Anton E., and Anthony J. D. Blake. "Concrete and Formal Thinking Abilities in High School Biology Students as Measured by Three Separate Instruments," Journal of Research in Science Teaching, 13: 227-235, May, 1976.

________, and John W. Renner. "A Quantitative Analysis of Responses to Piagetian Tasks and its Implications for Curriculum," Science Education, 58 (4): 454-559, 1974.

Linn, Marcia C., and Herbert D. Thier. "The Effect of Experiential Science on Development of Logical Thinking in Children," Journal of Research in Science Teaching, 12 (1): 49-62, January, 1975.

Longeot, F. "Analyse statistique de trois test genetiques Collectifs," Bulletin de l'Institut National D'Etude, 20 (4): 219-237, 1965.

________, "Un essai d'application de la psychologie genetique a la psychologie differentielle," Bulletin de l'Institut National D'Etude, 18 (3): 153-162, 1962.

McCurdy, D. W. "An Analysis of Qualities of Self-Directedness as Related to Selected Characteristics of ISCS Students," Science Education, 59 (1): 5-12, May, 1975.

Piaget, Jean. "Cognitive Development in Children: Piaget Development and Learning," Journal of Research in Science Teaching, 2: 176-186, 1964.

________. "A Structural Foundation for Tomorrow's Education," Prospects, 2 (1): 12-27, 1972.

Raven, Ronald J. "Logical Operations," Science Education, 57: 377-385, March, 1973.

________. "Programming Piaget's Logical Operations for Science Inquiry and Concept Attainment," Journal of Research in Science Teaching, 11: 251-261, March, 1974.

________, and H. Polanski. "Relationships Among Piagets Logical Operations, Science Content Comprehension, Critical Thinking, and Creativity," Science Education, 58 (4): 531-544, April, 1974.

Rowell, J. A., and P. J. Hoffmann. "Group Tests for Distinguishing Formal From Concrete Thinkers," Journal of Research in Science Teaching, 12 (2): 157-164, April, 1975.

Sayre, Steve, and Daniel W. Ball. "Piagetian Cognitive Development and Achievement in Science," Journal of Research in Science Teaching, 12 (2): 165-174, April, 1975.

Shayer, Michael, and David Wharry. "Piaget in the Classroom Part I: Testing a Whole Class at the Same Time," School Science Review, 55: 477-458, March, 1974.

Tisher, R. P. "A Piagetian Questionnaire Applied to Pupils in a Secondary School," Child Development, 42: 1633-1636, November, 1971.

UNPUBLISHED SOURCES

Ball, Daniel Wayne, and Steven Athol Sayre. "Relationships Between Student Piagetian Cognitive Development and Achievement in Science." Unpublished Doctoral dissertation, University of Northern Colorado, Greeley, 1972.

Friot, Faith Elizabeth. "The Relationship Between an Inquiry Teaching Approach and Intellectual Development." Unpublished Ph.D. dissertation, The University of Oklahoma, Norman, 1970.

Hale, James P. "An Investigation of Two Operational Schemata in Adolescents Enrolled in the ISCS Classrooms of Three Selected Teachers." Unpublished Ph.D. dissertation, The University of Iowa, Iowa City, 1972.

Sheehan, Donald J. "The Effectiveness of Concrete and Formal Instructional Procedures with Concrete and Formal Operational Students." Unpublished Ph.D. dissertation, State University of New York, Albany, 1970.

Teates, Thomas Gilbert. "A Comparison of Performance of ISCS and Non-ISCS Ninth-Grade Science Students on Several Piaget-Type Tasks." Unpublished Ph.D. dissertation, The Florida State University, Tallahassee, 1970.

Tisher, R. P. "The Development of Some Science Concepts: A Replication of Piagets Studies." Unpublished B.A. (Hons.) thesis, University of New England, Armidale, New South Wales, Australia, 1962.

APPENDICES

APPENDIX I

BACKGROUND DATA SHEET

Name ______________________________ Code Number ________

School ______________________________ Age ____ M ___ F ___

Number of school years in ISCS 1 ___ 2 ___ other _______

Elementary School Attended (grades 5 & 6) ____________________

Fifth Grade Science Teacher (72-73) ____________________

Sixth Grade Science Teacher (73-74) ____________________

Have you studied ESS (Elementary School Science)?

Fifth Grade: yes ___ no ___ don't know ___

Sixth Grade: yes ___ no ___ don't know ___

The following is a list of ESS Units. Please place the ones you remember studying.

___ Animal Activity

___ Animals in the Classroom

___ Crayfish

___ Colored Solutions

___ Heating and Cooling

___ Kitchen Physics

___ Peas and Particles

___ Microgardening - Structures

___ Daytime Astronomy

___ Batteries and Bulbs

___ Rocks and Charts

___ Optics

___ Starting from Seeds

___ Gases and Airs

___ Pond Water

___ Small Things

APPENDIX II

LEVEL II ISCS TEST

Name ____________________

ANSWER SHEET

Date ____________________

Where letters or numbers appear on the answer sheet, circle your choice or choices. Fill in the blanks with the appropriate answers on those that do not have letters or numbers. Show calculations on the back of your answer sheet when they are called for.

1.	A	B	C	D	E	15.	____________				
2.	A	B	C	D	E	16.	A	B	C	D	E
3.	____________					17.	A	B	C	D	E
4.	A	B	C	D	E	18.	A	B	C	D	E
5.	A	B	C	D	E	19.	A	B	C	D	E
6.	1.____________					20.	A	B	C	D	E
	2.____________					21.	A	B	C	D	E
	3.____________					22.	A	B	C	D	E
	4.____________					23.	A	B	C	D	E
7.	A	B	C	D	E	24.	A	B	C	D	E
8.	A	B	C	D	E	25.	A	B	C	D	E
9.	A	B	C	D	E	26.	A	B	C	D	E
10.	1.____	2.____	3.____	4.____		27.	A	B	C	D	E
11.	A	B	C	D	E						
12.	A	B	C	D	E						
13.	A	B	C	D	E						
14.	A	B	C	D	E						

APPENDIX III

ISCS ACHIEVEMENT TEST INSTRUCTIONS

(Distribute answer sheets to the students then the test booklets. The following instructions are to be read to the students).

1. This is a test of how well you recall what you studied last year in ISCS, Level II.

2. It is a part of the information needed by Mr. Lutes in his study. Please put your name and today's date on the answer sheet.

3. Remember to answer each question and do not write in the test booklet.

4. (Read aloud the instructions on the answer sheet. Emphasize that some questions ask for more than one answer, i.e. choices.)

5. You may take as much time as you need. Begin!

6. (Collect answer sheets, test booklets, and return them in the envelope provided.)

APPENDIX IV

SELECTION PROCEDURES FOR CELL DETERMINATION

1. All data for each student were placed on a card.

2. Cards were divided into two groups depending upon the students elementary background, Y or N.

3. The two groups were each divided into two groups using the scores on the IAT, U or L.

4. These four groups were again divided on the basis of LOL, F or C. This yielded eight groups of cards, one for each cell.

5. When more than the chosen number of cards were in a cell, the nearest out data were numbered and a table of random numbers used to select the cards not needed.

VITA

Loren D. Lutes was born in Pratt, Kansas, on January 2, 1943. He lived on a farm in Pratt County and attended elementary and high school in Byers, Kansas, where he graduated in 1961. During the next two years he completed the associate of arts degree at Friends Bible College in Haviland, Kansas. He completed his undergraduate work at the Kansas State Teachers College in Emporia, Kansas, graduating with the degree Bachelor of Science in Education in 1965.

Mr. Lutes taught science and math in Burlingame High School in 1965-66. The next three years, he taught physics and physical science at Campus High School in Wichita, Kansas. He completed work on his Masters Degree in Physics from Kansas State Teachers College in 1968. In 1969, he was appointed Instructor in Physics at the College of Emporia. He was named Assistant Professor in Physics and Department Head in 1971.

Before becoming Headmaster at Friendsville Academy, Friendsville, Tennessee, for the year 1974-75, he served as a consultant on energy education to the Special Training Division of Oak Ridge Associated Universities, Oak Ridge, Tennessee.

Study for the Doctorate in Education from the University of Tennessee began in 1974. He completed the Ed.D. with a major in Curriculum and Instruction in December, 1979. He was appointed Curriculum Coordinator for Fort Larned Unified School District, Larned, Kansas, in 1977.

Conference presentations include the presentation of the dissertation topic to the AETS regional conference. Among honors received are the following: Outstanding Educator of America, Who's Who in American Religion, and Who's Who in American Education.

He is married to the former Vera Marie Emley of Emporia, Kansas, and they have three children - Joel, Christine, and Phillip.