THE INFLUENCE OF SELECTED SCIENCE EXPERIENCES ON THE ATTAINMENT OF CONCRETE OPERATIONS BY FIRST GRADE CHILDREN

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ABSTRACT

THE INFLUENCE OF SELECTED SCIENCE EXPERIENCES ON THE ATTAINMENT OF CONCRETE OPERATIONS BY FIRST GRADE CHILDREN

by Donald Bernard Neuman

The main objective of this study was to investigate the influences of certain science experiences on the attainment of concrete operations by first grade children as revealed by selected Piagetian conservation tasks. These tasks involved the conservation of liquid quantity, conservation of continuous solid quantity, conservation of discontinuous solid quantity, and conservation of weight.

The study was carried out in Okemos, Michigan and involved all eighty-seven children in the three first grade classes and one first-second grade transition class in the Cornell School. At the outset of the study, each child was randomly assigned to one of four classes for the purpose of studying science. Two classes, designated as the experimental group by the investigator, studied science by means of the methods and materials developed by the Science Curriculum Improvement Study (SCIS). The other two classes, designated as the control group, studied science by means of the school's usual program.

For the purpose of determining differences in developmental growth between the experimental and control groups, all children were shown sixteen-millimeter color motion pictures of the four conservation tasks. Tape-recorded sound tracks consisting of information pertaining to the films and instructions for answering a question about each film were also presented to the children. The children were given a pre-test consisting of the four films. After an eighteen-week treatment period, all of the children were given a post-test consisting of the same four conservation films.

The data to which statistical tests were applied were obtained from the results of the conservation tests. Parametric and non-parametric models were used to analyze these data. On the basis of the analyses, the following conclusions were indicated:

1. There were no differences in the attainment of concrete operations between children who studied science by means of the SCIS program and children who studied science by means of the usual program.
2. There were no differences in the attainment of concrete operations between boys and girls.
3. The girls who studied science by means of the SCIS program scored significantly higher on the post-test than on the pre-test.

4. No conclusive evidence was produced to indicate a dominance of the experience factor in promoting attainment of concrete operations.
5. Children appeared able to conserve weight at the same age that they conserved quantity.

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By

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CHAPTER I

INTRODUCTION

Science educators have been interested in promoting and improving elementary school science for more than one hundred years.[1] As early as 1860, "object teaching," which emphasized description of animate and inanimate objects and was based on the theoretical work of Pestalozzi, was made the basis for virtually all of the elementary science taught in the United States.[2] A shift in emphasis occurred near the end of the Nineteenth Century. The theories and practices of Hall, Parker, and Jackman resulted in the "nature study" movement. This movement lent strong support for the use of science as the unifying principle in elementary school curricula.[3]

By the 1920's, enthusiasm for "nature study" waned and new ideas were beginning to make an impact on science

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[1]Herbert A. Smith, "Historical Background of Elementary Science," in Edward Victor and Marjorie Lerner (Eds.), *Readings in Science Education for the Elementary School* (New York: The MacMillan Company, 1967), p. 34.

[2]*Ibid*.

[3]*Ibid*., p. 36.

instruction. Peirce and James contributed a theory of pragmatism in which the link between concept and experience was considered fundamental. About the same time, Dewey stated that the methodology of science was of equal or greater importance than the actual knowledge accumulated.[4] The works of Peirce, James, and Dewey contributed greatly to the eventual development of the inquiry approach to science in the 1930's.

An important step forward in science education took place in 1932 when the Thirty-First Yearbook of the National Society for the Study of Education[5] was published. This yearbook stressed the need for an integrated K-12 science program and outlined the major generalizations of science as objectives of instruction. The influence of this yearbook was exemplified by the great amount of research devoted to identifying major principles of science and their relationship to general education that took place in the years following its publication.[6] Two subsequent

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[4] *Ibid.*, p. 37.

[5] National Society for the Study of Education, *A Program for Teaching Science*, Thirty-First Yearbook, Part I (Bloomington, Indiana: Public School Publishing Company, 1932).

[6] Smith, *op. cit.*, p. 39.

yearbooks,[7,8] published by the Society, attempted to bring the content material of the Thirty-First Yearbook up-to-date and to place emphasis on the importance of science education in a society becoming increasingly more dependent on the products of science and technology.

By the middle years of the 1950's, interest in the quality of the science education American children were receiving had become widespread. Scientific discoveries and advanced methodology had stimulated scientists, educators, and the general public to recognize the need to upgrade and update science programs at all levels of American education. The Soviet Union's spectacular and highly publicized Sputnik success in 1957 added a sense of urgency to the new wave of interest in science education. Concern over what was wrong with general education, and in particular, what was wrong with science education, brought the influence of the Federal Government into the picture through such agencies as The National Science Foundation and the United States Office of Education.

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[7]National Society for the Study of Education, Science Education in American Schools, Forty-Sixth Yearbook, Part I (Chicago: University of Chicago Press, 1947).

[8]National Society for the Study of Education, Rethinking Science Education, Fifty-Ninth Yearbook, Part I (Chicago: University of Chicago Press, 1960).

Within a year of the Sputnik launching eleven projects designed to revamp the science curriculum had been initiated at a number of American universities.[9] Included among these eleven were projects whose purposes were to redesign the curriculum in each of the major areas of science education--physics, chemistry, biology, earth science, general science, and elementary science.

Four goals shared by all of the projects were:

1. Updating the content of science curriculum materials.
2. Emphasizing the processes of science.
3. Stimulating pupil inquiry by setting problem solving situations for the pupils.
4. Providing manipulative materials to augment course content.

As the movement for science curricular changes grew into a veritable national movement, the theoretical work of Jean Piaget became of interest to many of the individuals associated with the developing science projects. Jean Piaget, a biologist, epistemologist, and developmental psychologist, had been at work for almost forty years at the International Center of Genetic Epistemology in Geneva, Switzerland. Between 1918 and 1958 he had published almost

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[9]J. David Lockard, Report of the International Clearinghouse on Science and Mathematics Curricular Developments (College Park, Maryland: University of Maryland, 1967).

two hundred articles and thirty books.[10] It was not, however, until the latter half of the 1950's that Piaget's findings had any marked impact upon the thinking of educators in the United States.

Piaget's investigations were concerned with how children react to certain known facts; how children behave in a problem solving situation; how the structure of the child's developing intellect evolves through a series of increasingly more complex ontogenetic stages; and how the structure of knowledge can best be arranged to coincide with the structures of the child's intellect at a particular time in the developmental sequence.

Although Piaget's work stressed cognitive development, his findings pointed to relationships between how children grow and how they learn. These findings and the implications that they have for setting learning situations furnished the bases for the thinking that has been associated with the development of some of the methods and materials which have been incorporated into certain of the current science curriculum projects.

Need for the Study.--A recent report[11] indicates that at least twenty-one unique and independent science projects are being developed at the present time. While

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[10] David Elkind, "Giant in the Nursery," New York Times Magazine, May 26, 1968.

[11] Lockard, loc. cit.

no reliable count is available on the percentage of elementary schools that have adopted new science programs,[12] this investigator's review of the literature and personal conversations with science teachers in elementary schools lead him to believe that the number is fewer than ten per cent. Thus, it seems reasonable to assume that a large number of elementary schools can be expected to examine one or more of the newer programs when science curriculum changes are undertaken.

In examining the newer science programs, schools should consider the degree to which the goals of the new program coincide with the general and specific objectives of the schools. It is the opinion of this writer that one objective of all schools in America should be the maximum development of each child to that child's fullest intellectual potential. Thus, changes in curriculum should be considered by the school in terms of the influence of the new curriculum on a child's intellectual behavior. These behavioral changes, called developmental growth, represent changes in the individual's perceptions and thinking as he passes through an ordered and invariant series of intellectual stages. In this sense, developmental growth is frequently referred to as ontogenetic growth.

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[12] Wayne Welch, "The Impact of National Curriculum Projects--The Need for Accurate Assessment," _School Science and Mathematics_, 68:225-234, March, 1968.

Many of the new elementary science projects claim, as one of their major goals, the intellectual development of children who study science by means of their methods and materials. For example, two of the most influential elementary science programs presently being implemented in America, Science--A Process Approach,[13] developed by the Commission on Science Education of the American Association for the Advancement of Science (AAAS) and the Science Curriculum Improvement Study (SCIS),[14] developed under the leadership of Karplus and Thier at the University of California at Berkeley, are concerned with developmental growth. Although the approaches and the conceptual emphases of these two programs are quite different, key aspects of their respective goals are of a developmental nature. The AAAS science program, which is heavily process oriented defines process in the following terms:

> The third and perhaps most widely important meaning of process introduces the consideration of human intellectual development. From this point of view, processes are in a broad sense 'ways of processing information'. Such processing becomes more complex as the individual develops from early childhood onward.[15]

The Commission on Science Education of AAAS also states that:

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[13]Robert Gagne, Science--A Process Approach, Pamphlet 67-12, 1967.

[14]Robert Karplus and Herbert Thier, A New Look at Elementary School Science (Chicago: Rand McNally Company, 1967).

[15]Gagne, op. cit., p. 4.

> Science--A Process Approach attempts to deal realistically with the development of intellectual skills, in the sense that the goals to be achieved by any single exercise are modest. In a longer-term sense, substantial and general intellectual development is an orderly progression of learning activities.[16]

The SCIS program, which is more conceptually oriented, also describes its goals in developmental terms:

> The program of the Science Curriculum Improvement Study is aimed at . . . [helping] the children's intellectual development reach the formal operational level. . . .
> The premise of our program is that it is possible for the school to have a conscious influence on the development of its pupils in order to produce a more significant and a more useful understanding of natural phenomena by the time they are in their teens.[17]

Purpose of the Study.--The main purpose of this study was to investigate the influence of certain science experiences as developed by SCIS, on the developmental growth of first grade pupils as reflected in their performance on selected Piagetian conservation tasks. These tasks involved the conservation of liquid quantity, conservation of continuous solid quantity, conservation of discontinuous solid quantity, and conservation of weight.

The experiences were provided to the children by means of the methods and materials of a science program

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[16] Ibid., p. 5.

[17] Robert Karplus, "The Science Curriculum Improvement Study," in Piaget Rediscovered: A Report on the Conference on Cognitive Studies and Curriculum Development, Part III, ed. by R. E. Ripple and V. N. Rockcastle (Ithica, New York: Cornell University, 1964), pp. 113-118.

developed after 1958. The affect on the developmental growth of a child was determined by his acquisition of the concrete operational stage. Acquisition of the stage was signified by the child's ability to conserve three kinds of quantity--liquid, continuous solid, and discontinuous solid quantity. In addition to the main purpose, the study was also designed to investigate the differential rates of achievement of conservation of quantity and weight in the children who served as subjects for this research.

Background.--In mid-1967 Michigan State University actively became a Trial Center for the Science Curriculum Improvement Study (SCIS) program. During the summer of 1967, the superintendent of schools in Okemos, Michigan contacted the Trial Center Coordinator at the University concerning the possibility of using SCIS materials in a school in Okemos.

The Trial Center coordinator invited the investigator to design a study that would provide useful information about the SCIS program to both the Trial Center and the Okemos School District. After a series of meetings involving both school district and university personnel the present study concerning the influence of the experiences associated with the SCIS program on a child's attainment of the concrete operational stage was undertaken.

Design of the Study.--The design of the study provided for an experimental group of pupils and a control group. Eighty-seven first grade and first-second grade (transition) pupils of the Cornell School, Okemos, Michigan, were randomly assigned by sex to four teachers for instruction in science. Two of the classes were arbitrarily designated the experimental group. These pupils were taught science by means of the methods and materials prescribed in the SCIS elementary science program. The two remaining classes constituted the control group. The control pupils received the school's regular science program for first grade children.

The study began in January, 1968. A pre-test, consisting of filmed adaptations of four Piagetian conservation tasks, was administered at the beginning of the investigation. The treatment period was of eighteen weeks duration, and the classes met for three thirty minute sessions per week. At the completion of the treatment period, a post-test consisting of the same filmed adaptations of Piaget conservation tasks was administered.

Hypotheses.--This study was designed to measure developmental growth in first grade children exposed to different kinds of science experiences. Determination of developmental growth was based on a child's ability to recognize the invariance of quantity and weight of an object in the face of physical deformations involving that object.

Seven research hypotheses were proposed by the investigator for the purposes of designing and carrying out the study. They were as follows:

1. Children who study science by means of SCIS methods and materials will score higher on a test of conservation of quantity than children who have the usual science program.

2. Girls will score higher than boys on a test of conservation of quantity.

3. There is a difference in the proportion of girls and boys who conserve after studying science by means of SCIS methods and materials as compared to studying science by means of the usual program.

4. More children who study science by means of SCIS methods and materials will conserve weight than children who have the usual science program.

5. More children who study science by means of SCIS methods and materials will conserve liquid quantity than children who have the usual science program.

6. More children who study science by means of SCIS methods and materials will conserve continuous solid quantity than children who have the usual science program.

7. More children who study science by means of SCIS methods and materials will conserve discontinuous solid quantity than children who have the usual science program.

Definitions.--For the purpose of this study, certain terms were used in accordance with the following explanations and/or defintions:

1. Stage. Cognitive development takes place in levels or steps characterized by the progressive organization of the composite structures of

mental operations. Each structure constitutes attainment of one level and the starting point of the next level.[18] Such a level was interpreted as a stage of development.

2. Pre-operations. This is the developmental stage typical of a two to seven year old child. This stage as described by Piaget and his co-workers is marked by the following characteristics:

   a. Egocentrism--the child neither feels the compunction nor is able to make judgments from points of view other than his own.

   b. Centration--the child shows a tendency to center his attention on a single, striking feature of an object to the total neglect of other aspects of that object.

   c. Disequilibrium--a principal characteristic of the pre-operational child is the absence of a stable equilibrium between what a child perceives and what he is capable of understanding.

   d. Irreversibility--a cognitive organization is irreversible if it cannot pursue a series of reasonings or follow a series of

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[18] Barbel Inhelder, "Aspects of Piaget's Genetic Approach to Cognition," in Thought in the Young Child by W. Kessen and C. Kuhlman, editors, Monograph, Society for Research in Child Development, 1962, No. 83, p. 23.

transformations and then reverse direction in thought and find again the point of departure.[19]

3. Concrete operations. This is the stage at which the child's thoughts acquire increased flexibility. Concrete operations manifest themselves in the child's ability to shift back and forth between part-part and part-whole relationships for classes and sub-classes and in the ability to function intellectually on tasks requiring reversibility, decentration, serial ordering, and adding and multiplying of classes.[20]

4. Conservation. A particular experienced quality; matter, weight, volume, number, or area is perceived as invariant by the child regardless of the physical transformations in state or shape that might be observed.[21]

5. Conservation of quantity. Conservation of quantity is sometimes called conservation of matter. When a child observes a physical

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[19]Flavell, op. cit., pp. 156-159.

[20]J. McVicker Hunt, Intelligence and Experience (New York: Ronald Press, 1961).

[21]Barbel Inhelder and Jean Piaget, The Growth of Logical Thinking from Childhood to Adolescence (New York: Basic Books Inc., 1958), p. 32.

rearrangement of an amount of matter, and he is able to conserve he will realize that there is no change in the total quantity of matter. He will recognize that a change in one physical dimension is compensated by a concomitant change in another dimension. In this study, conservation of quantity is composed of three sub-tasks: conservation of liquid quantity, conservation of continuous solid quantity, and conservation of discontinuous solid quantity.

6. Non-conservation. The inability of a child to recognize the invariance of various empirical factors, such as weight or number, as they are physically transformed signifies that the child is at a less advanced stage of intellectual development. The youngster's thought processes have not developed to the point where they can correct for what Heraclitus called the "illusory flux of appearances"[22] or what Bruner terms "perceptual seduction."[23]

7. Transition. The child's thought processes do not usually evolve directly from a state of

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[22]Hunt, <u>op. cit.</u>, p. 205.

[23]Jerome Bruner, "On the Conservation of Liquids," in <u>Studies in Cognitive Growth</u>, by J. Bruner, R. Olver, and P. Greenfield, editors (New York: John Wiley and Sons, Inc., 1966), Chapter 9, p. 189.

non-conservation to conservation but appear to go through an intermediate state marked by indecision and vacillation. Sometimes the child asserts conservation of an empirical factor while later he denies conservation of the same factor. Often he is "seduced" first by one dimension of a display, then by another dimension.

8. Acceleration. In accordance with the literature, acceleration is used interchangeably with induction in this study. Both terms infer that the acquisition of a developmental stage has been speeded up.

Assumptions and Limitations.--In designing this study the following assumptions were made:

1. Piagetian-like conservation tasks were appropriate for standardization on film and audio tape.
2. The filmed conservation tasks were valid for evaluation purposes.
3. One criterion for measuring the success of a science program was how well it facilitated or accelerated achievement of higher-order developmental stages.
4. Children were constantly exposed to instructional materials such as television and motion pictures in the schools. Therefore the input of stimuli (for evaluation purposes) by means of filmed

sequences was consonant with usual operating procedures in the classroom.

5. Indication that a child conserved matter signified that the child had achieved the stage Piaget calls concrete operations.
6. The Hawthorne effect was controlled by providing both the treatment and control groups with additional materials and equipment.
7. Internal validity was controlled by random assignment of pupils to the two treatments.
8. Teachers using SCIS materials followed the teacher's manual very closely and taught all of the agreed-upon activities.
9. The pre-test was of no significant learning value.
10. Information about teaching methods and materials was not exchanged between experimental and control group teachers.

The following are recognized limitations of this study:

1. The small size of the population and the fact that it was drawn from one school in a rural-suburban community limited the generalizability of this study.
2. The small number of films and limited test score range limited the chances of statistical significance.

3. Limited aspects of the concept conservation were tested by the films. These were conservation of quantity and conservation of weight.

<u>Overview of the Thesis</u>.--The need, purposes, general design, definitions, assumptions and limitations of this study have been presented in this chapter. A description of certain theoretical aspects of Piaget's developmental theory and studies that have replicated or extended this theory make up Chapter II. The population, treatment, and methods of evaluation used in this study are presented in Chapter III. Chapter IV contains the results and analyses of the data. Conclusions of this study and recommendations for further investigation are reported in Chapter V.

CHAPTER II

REVIEW OF LITERATURE

This chapter reviews the literature relative to the theoretical bases upon which the present study was built. A brief statement of Piaget's stage-related theory is presented along with a more detailed discussion of the concrete operational phase and the concept of conservation. The factors believed chiefly responsible for accelerating acquisition of higher stages are noted. Studies related to the theory conclude the chapter.

Overview of the Theory.--General descriptions of Piaget's developmental theory abound in the literature. Works by Piaget,[1] Inhelder and Piaget,[2] Hunt,[3] Flavell,[4]

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[1]Jean Piaget, "Development and Learning," in *Piaget Rediscovered: A Report of the Conference on Cognitive Studies and Curriculum Development*, Part I, ed. by R. E. Ripple and V. N. Rockcastle (Ithica, New York: Cornell University, 1964), pp. 7-19.

[2]Inhelder and Piaget, *op. cit.*

[3]Hunt, *op. cit.*

[4]John Flavell, *The Developmental Psychology of Jean Piaget* (Princeton, New Jersey: D. Van Nostrand Company, Inc., 1963).

Adler,[5] Boehm,[6] Huttenlocher,[7] and Stendler[8] provide rather complete and detailed descriptions of the various stages, sub-stages, periods, and phases that make up Piaget's developmental scheme.

In order to discuss the Piagetian system, some agreement on terminology is necessary. In discussing Piaget's various developmental levels Hunt[9] pointed out that Piaget and his collaborators, ". . . have been inconsistent with both terms and numberings. Each successive book has its own."

Thus, the following table of terminology, based in the main on terminology suggested by Hunt,[10] is provided to serve as a guide for subsequent discussion. The table appears on the following page.

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[5]Marilynne Adler, "Some Educational Implications of the Theories of Jean Piaget and J. S. Bruner," Canadian Educational Research Digest, 4:291-305, December, 1964.

[6]Lenore Boehm, "Exploring Children's Thinking," Elementary School Journal, 61:363-373, April, 1961.

[7]Janellen Huttenlocher, "Children's Intellectual Development: Piaget's Position," Review of Educational Research, 35:117-118, April, 1965.

[8]Celia Stendler, "Aspects of Piaget's Theory that Have Implications for Teacher Education," Journal of Teacher Education, 16:329-335, September, 1965.

[9]Hunt, op. cit., p. 113.

[10]Ibid., p. 114.

TABLE 1.--Piagetian terminology as suggested by Hunt.[a]

Periods	Stages	Phases
A. Sensory motor period (birth to two years)	1. Exercising ready made schemata (birth to one month old) 2. Primary circular reactions (one month to four months old) 3. Secondary circular reactions (four months to nine months old) 4. Coordination of secondary schemata (nine months to twelve months old) 5. Tertiary circular reactions (twelve months to eighteen months old) 6. Internalization of sensory motor schemata (eighteen months to two years old)	
B. Operational period (two years to twelve years old)	1. Pre-operational stage (two years to seven years)	a. Symbolic or pre-conceptual phase (two years to four years old) b. Intuitive phase (four years to seven years old)
	2. Concrete operational stage (seven years to twelve years old)	
C. Formal operational period (twelve years old through adolescence)		

[a]J. McVicker Hunt, Intelligence and Experience (New York: Ronald Press, 1961), pp. 113-115.

The Piagetian system consists of three periods: the sensory-motor period, the operational period, and the formal operational period. Each period is in turn subdivided into stages or phases. For example, the sensory-motor period is divided into six stages during which intentions, means-ends differentiations, and interest in novelty develop.

The operational period is marked by two stages: the pre-operational stage and the concrete operational stage. The pre-operational stage is divided into two phases: the preconceptual phase and the intuitive phase. During the operational period symbols become operational, language develops, the child continually extends, differentiates, and corrects his intuitive impressions of reality, and his central processes become more and more autonomous.[11]

The final period, formal operations, is not subdivided as such. The operational capabilities of the adolescent are, however, carefully spelled out. During this period the individual is able to group and systematize concrete operations, classify and order in verbal propositions, and operate with the sum total of possibilities, not merely the immediate, observable situation.[12]

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[11] *Ibid.*, p. 114.

[12] *Ibid.*, p. 115.

Concrete Operational Stage.--This study was based on the premise that accelerating children's attainment of the concrete operational stage is possible.

According to Flavell:[13] concrete operations can be defined as the time in life when a child acquires a well-structured and coherent cognitive framework, the child can describe the concrete, perceivable world of things or events.

Piaget describes the concrete operational stage in this way:

> I call these concrete operations because they operate on subjects, and not yet on verbally expressed hypotheses. For example there are the operations of classification, ordering, the construction of the idea of number, spatial and temporal operations, and all the fundamental operations of elementary logic of classes and relations.[14]

A new and exciting intellectual world is opened for the child who has achieved concrete operations. Attainment of this stage is based on an organization process. "What are organized are active, intellectual operations: their organization into systems with definable structure is the 'sine qua non' for 'good cognition', i.e., cognition of greater genetic maturity."[15]

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[13]Flavell, op. cit., pp. 164-165.

[14]Piaget, op. cit., p. 9.

[15]Flavell, op. cit., p. 168.

To fully understand the significance of achieving the concrete operational stage one should compare the pre-operational child with the concrete operational child. The pre-operational child attempts to solve all new problems by modes that have been successful in the past. Such modes frequently produce contradictions which the pre-operational child ignores. He continues merely to interact with the problem situation with the result that his conceptual structures are in no way affected. Typical of this is the child's tendency to center his attention on one quantitative dimension of an object, regardless of the physical deformations imposed on the object. The child continues to base all of his judgments of quantity on just that one dimension. As a result, the pre-operational child may judge the quantity of water in two glasses by considering only the height of the water in each glass. He ignores the width completely.

Physical appearances dominate the perceptions of the pre-operational child. For example, clustering of a group of objects causes the child to report an increase in the total mass of the objects, while the spreading out of those same objects generates a report of reduced total mass.

At this stage, the child's thought is irreversible. A ball of clay whose shape is changed cannot be returned to its original shape in the mind of the child. When water is poured from a vessel of one shape into a vessel of a different shape, the child is unable to consider the results of pouring the water back into the original container.

The concrete operational child, on the other hand, is able to perform a variety of mental operations. Flavell,[16] in discussing the Piagetian system, describes a child at the concrete operational stage as being able to:

1. Compose and decompose classes in a hierarchy.
2. Combine elementary classes into supraordinate classes and decompose supraordinate into subordinate classes.
3. Mentally destroy one classification system in order to impose a new and different system on the data.
4. Find the intersect or logical product of two or more classes.
5. Build up elements into a transitive, asymmetric series--that is, serial order a set of elements.
6. Recognize commutative properties of sets of objects.
7. Build, from constituent elements, multiplication-of-relations matrices so that relations such as "shorter than and wider than" can be logically multiplied to equal "taller than and thinner

[16] Flavell, op. cit., p. 191.

than." Multiplication of relations is the basic solution for virtually all conservation problems.

In addition to Flavell's list of characteristics, Hunt[17] states that the concrete operational child can:

1. Associate several objects or operations in a varied order, realizing that it makes no difference which are combined first (a+b+c=c+a+b).
2. Use the property of identity to demonstrate that an operation is nullified by combining it with its opposite (all boys except those who are boys equal noboby or 1 + (-1) = 0).
3. Recognize the implications of a tautology. For example a child recognizes that repeating a message adds no new information to that message.

Inhelder also provides a list of intellectual characteristics deemed useful for describing a concrete operational child. In addition to characteristics already enumerated, Inhelder[18] states that a concrete operational child can:

1. Structure thought processes in such a way as to make clear the reversibility of operations.
2. Form a system of reciprocal relations which result in a realization that two or more people

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[17] Hunt, op. cit., p. 201.

[18] Inhelder, op. cit., pp. 19-40.

looking at the same object from different spatial locations may see different things.

In summary, the concrete operational child learns to distinguish the world from the self. Accidental occurrences become differentiated from cause and effect happenings. The child learns to perform internalized mental operations on what he observes. The child is no longer the slave of his own immediate perceptions. He is able to analyze the implications of what he directly perceives in terms of multiple classifications, reverse operations, serial ordering, multiple combinations, complex associations, and identities.

Conservation.--The concept of conservation is basic to many of the tasks used by Piaget and others in determining developmental growth at the concrete operational stage. Piaget states:

> Every notion,whether it be scientific or merely a matter of common sense, presupposes a set of principles of conservation. . . . the introduction of the principle of inertia (conservation of rectilinear and uniform motion) made possible the development of modern physics, and the principle of conservation of matter made modern chemistry possible. . . . In the field of perception the schema of the permanent object presupposes the elaboration of what is no doubt the most primitive of all these principles of conservation. Obviously conservation, which is a necessary condition of all experience and all reasoning, by no means exhausts the representation of reality. . . . Our contention is merely that conservation is a necessary condition for all rational activity.[19]

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[19]Jean Piaget, The Child's Concept of Number (New York: Norton and Company, 1965), p. 3.

Flavell notes that, from the developmental point of view, conservation involves the:

> . . . cognition that properties (quantity, number, length, etc.) remain invariant (are conserved) in the face of certain transformations (displacing objects or object parts in space, sectioning an object into pieces, changing its shape, etc.).[20]

One of the most widely known and publicized Piagetian experiments concerns the conservation of liquid quantity. A child is shown two equal-size beakers, each containing the same amount of water. The child is invited to examine the beakers to insure that each contains the same amount of water. Then, before the child's eyes, the water from one of the beakers is poured into a beaker of different dimension, for example one that is taller and thinner than the original. A physical transformation is observed by the child. After the water is poured, the child is asked whether the quantity of liquid in the new container is greater than, less than, or equal to the quantity of water in the original beaker.

Piaget asserts that the child's answer is dependent on the developmental stage of that child. There are four answers possible and each is related to a major cognitive step leading ultimately to the evolution of conservation of quantity.

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[20]Flavell, op. cit., p. 245.

Step I. The child attends only to the height of the liquid in the containers. Thus, when water is poured into a tall thin container and compared to the original beaker the child perceives the greater height to represent the greater quantity and answers that there is more water in the tall glass.

Step II. The child attends only to the width of the liquid in the container. Consequently the child perceives the shorter-wider amount as being greater than the tall-thin amount and reports this back to the investigator.

In either case, Step I or Step II, the child centers on one dimension and becomes deluded by the "attraction" of that one property.

Step III. At this step in the ontogenetic process, the child's behavior becomes somewhat hazy. It is apparent that a coordination between steps I and II takes place. That is, the child for the first time is able to center on both height and width. However, the child is not yet sophisticated enough to recognize quantitative compensation of height and width. He therefore displays noticeable hesti-tation and conflict. Often he will tell the exper-imenter that he is not sure or is confused.

Step IV. At this step, the child realizes that the increase in height of the liquid in a container is entirely compensated for by a decrease in width. The child reports unequivocally that there is the same amount of water regardless of the shapes of the containers. There is:

> . . . a shift of conceptual focus from 'states' alone to the 'transformations' which lead from state to state. . . . The outcome of this fourth and final step is, of course, a rigorous conservation of quantity.[21]

For convenience these four steps are often reduced to three stages of conservation. Steps I and II are termed the non-conservation stage; step III is called the transition stage; and step IV is called the conservation stage. Piaget has devised experiments that demonstrate a number of conservation tasks: weight, volume, number, area, and quantity of matter.

<u>The Role of Conservation in Concrete Operations</u>.--A basic feature of the attainment of the concrete-operational stage is the relationship between conservation and concrete operations. This relationship has been the source of much theoretical and experimental work. Flavell states:

> There is no question but that the formation of concrete operations is the richest chapter in Piaget's developmental story in the sense of sheer abundance of highly interesting empirical data. It does not seem likely that all this would or

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[21]Flavell, <u>op. cit.</u>, p. 246.

> could have come about without the concept of conservation formation and related unifiers.[22]

Carlson[23] states: "The ability to conserve is the key development of the period of concrete intelligence."

Despite the importance of conservation and its careful description and analysis by Piaget, Inhelder, and others, the relationship between conservation and concrete operations appears somehow to have become obscured. The fault, in part, is in Piaget's literary style. His inconsistent use of terminology and his complex phraseology combine with the problems of translating French into English to create difficulties in theoretical interpretation.

Flavell, in his critique of Piaget's work states:

> There is a great deal of vagueness, imprecision, instability of concept definition, and other obstacles to communication in Piaget's theoretical writings. One often has to work hard to understand what Piaget is trying to say, and he does not always succeed in this end.[24]

Some experimenters contend that a child must be able to conserve before that child can adequately function at the concrete-operational level. Saying this in another way, they believe that if one were able to induce conservation in a child, he would at the same time "propel"

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[22]*Ibid.*, p. 415.

[23]J. S. Carlson, "Developmental Psychology and Its Implications for Science Education," *Science Education*, 51:246-250, April, 1967.

[24]Flavell, *op. cit.*, p. 427.

that child into the concrete operational stage. It seems that this is what Sigel and Roeper mean when they state:

> . . . this ability to conserve is a necessary intellectual operation that enables a child to make the transition from the pre-operational period to that of concrete operations.[25]

Brison[26] follows a similar line of reasoning when he discusses the relationship between conservation and the operations of reversibility and decentration. One is led to believe that conservation is the precursor of concrete operations rather than the child's way of expressing his understanding of reversibility and decentration. Bruner[27] and Brison[28] have taken a similar theoretical position. However, others interpret Piaget's position to be that operational thought is the consequence of modification of mental structures and results _in_ conservation, not _from_ conservation.

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[25]Irving Sigel and Annamarie Roeper, "The Acquisition of Conservation: A Theoretical and Empirical Analysis," p. 1. (Mimeographed.)

[26]David Brison, "Acceleration of Conservation of Substance," _The Journal of Genetic Psychology_, 109:311-322, 1966.

[27]Jerome Bruner, "The Course of Cognitive Growth," _American Journal of Psychology_, 19:1-16, 1961.

[28]David Brison, "Acquisition of Conservation of Substance in a Group Situation," _Dissertation Abstracts_, 26:2583, No. 5, 1966.

Duckworth[29] points out that in Piaget's research, when a child asserts that liquid is conserved, this is taken as an indication of a certain structure of mental operations. The child recognizes the difference between "appearance and reality" and is able to indicate this through "reversibility of thought and a capacity for logical multiplication."[30] Logical operations make it possible for a child to justify conservation of quantity in spite of variations in appearance. Conservation should therefore be considered a diagnostic tool for measuring developmental growth, not a pole for vaulting the child to a higher level of intellectual development.

Acceleration of Concrete Operations.--One of the controversial topics relative to the concept of concrete operations concerns whether or not acquisition of such operations can be accelerated. Some researchers indicate that they may be. Others say that they cannot be accelerated. Piaget's reaction is, "Oh you Americans, you are in a rush always."[31]

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[29]Eleanor Duckworth,"Piaget Rediscovered," in Piaget Rediscovered: A Report of the Conference on Cognitive Studies and Curriculum Development, Part I, R. E. Ripple and V. Rockcastle, editors (Ithica: Cornell University, 1964), pp. 1-5.

[30]Hunt, op. cit., p. 207.

[31]Lydia Muller-Willis, "Learning Theories of Piaget and Mathematics Instruction," in Improving Mathematics Education for Elementary School Teachers, edited by W. Robert Houston (East Lansing, Michigan: Michigan State University, 1960), Section II, p. 41.

Piaget believes that the child must be biologically ready to move to a more advanced developmental stage. Educational efforts are limited by the child's developmental sequence. However, in a 1964 speech at Cornell University he clarified his position somewhat by stating that the acceleration of stages such as concrete operations

> . . . is possible if you base the more complex structures on simpler structures, that is when there is a natural relationship and development of structures and not simply an external reinforcement.[32]

This last statement has produced a general feeling among psychologists and educators that acceleration of developmental stages can be accomplished if the factors responsible for the growth of simple structures can be described.

Piaget describes the factors that he believes affect attainment of concrete operations in the following way:

> It seems to me there are four main factors; first of all, maturation, in the sense of Gesell, since this development is a continuation of embryogenesis; second the role of experience of the effects of the physical environment on the structures of intelligence; third, social transmission in the broad sense (linguistic transmission, education, etc.); and fourth, a factor which is too often neglected but one which seems to me fundamental and even the principal factor. I shall call this the factor of equilibration.[33]

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[32] Piaget, <u>op. cit.</u>, p. 17.

[33] <u>Ibid</u>., p. 10.

Piaget[34] considers maturation to be a ripening of neural structures with age. Although maturation plays an indispensible role, he believes it is insufficient in itself for explaining achievement of concrete operations. The chronological age at which this stage is reached varies by as much as four years in different cultures. Studies indicate that children in urban centers such as Geneva, Montreal, and Teheran tend to attain concrete operations at approximately the same age. Studies involving rural Iranian populations indicate a two year lag in reaching the operational stage. Children in Martinique are four years behind the urban groups as measured by the Piagetian experiments. Therefore, neural maturation cannot alone explain developmental growth.

Piaget[35] believes that experience, too, is necessary, but insufficient for bringing about concrete operational thought. Concepts appear at the onset of this phase that cannot be explained by experience. The child is able to conserve the quantity of matter before he can conserve the weight of that same matter. Yet conservation of quantity cannot be directly measured by the child while conservation of weight can. It is difficult to explain how experience can enable an abstract concept like quantity to become a part of a child's intellectual

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[34] Ibid.

[35] Ibid., p. 11.

structure before a more concrete concept like weight does.

A third factor, social transmission, which can be interpreted to mean linguistic or educational transmission is also deemed insufficient to promote significant developmental growth by itself. This is because the child can receive information by means of language or education from an adult only if he has reached a point in his intellectual development where he can assimilate and accommodate to that information.

Equilibration, the fourth factor, is for Piaget the critical one. When a child is confronted with a cognitive conflict and he actively operates to compensate for the conflict, logical structures develop. Compensation is achieved through the operations of reversibility, associativity, additive composition, identity, and affirmation of equivalence among members of a class.[36]

From a theoretical point of view there appears ample reason to believe that:

1. Conservation of quantity is indicative of achievement of concrete operations.
2. Earlier acquisition of concrete operations is significant to a child's educational progress.
3. Acceleration of concrete operations is possible.[37]

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[36] Ibid., p. 14.

[37] Millie Almy, Edward Chittendon and Paula Miller, Young Children's Thinking: Studies of Some Aspects of Piaget's Theory (New York: Teacher's College Press, 1966), p. 131.

Experimental confirmation of Piaget's theory and a description of studies that demonstrate factors that accelerate acquisition of concrete operations will make up the remainder of this chapter.

Studies Concerned with the Basic Theory.--The literature reviewed reveals that studies replicating Piaget's stage theory have confirmed, almost without exception, the existence of developmental stages and their invariant order of achievement. A number of studies have, however, disagreed with Piaget on the age at which particular stages appear.

Peel[38] conducted four studies in Great Britain each involving from thirty-two to sixty children. These children were presented with Piagetian tasks related to the child's perceptions and logical thinking. The validity of Piaget's schemata was assessed by comparing development of children's thinking and perception with the criteria of chronological and mental age. In general, Piaget's conclusions about order of stage development were substantiated in these studies.

Dodwell[39] conducted a study involving 250 kindergarten pupils. Three stages in the development of number

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[38] E. A. Peel, "Experimental Examination of Some of Piaget's Schemata Concerning Children's Perceptions and Thinking and a Discussion of Their Educational Significance," British Journal of Educational Psychology, 29:89-103, June, 1959.

[39] P. C. Dodwell, "Children's Understanding of Number and Related Concepts," Canadian Journal of Psychology, 14: 191-205, 1960.

were identified. These stages were global, intuitive, and concrete operational. It may be noted that Dodwell's evidence corroberated Piaget's stage theory.

Hood[40] working with 126 normal children, age four years, nine months to eight years, seven months and forty subnormal mental-status children and adults, age ten years, three months to forty-one years showed that the sequence of development was the same for all of the children, but that retarded children and subnormal adults required a longer time to reach the higher stages of intellectual development.

Goodnow[41] studied Hong Kong children and Price-Williams[42] used illiterate bush West African children as subjects. Both were able to replicate Piaget's findings on stage order. However, questions regarding relative age of acquisition of certain stages were raised.

Woodward[43] conducted a series of experiments in which he was able to validate the six stages of the

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[40]H. B. Hood, "An Experimental Study of Piaget's Theory of Development of Number in Children," British Journal of Psychology, 53:273-286, 1962.

[41]Jacqueline Goodnow, "A Test of Milieu Effects with Some of Piaget's Tasks," Psychological Monographs, Vol. 76, No. 36, 1962.

[42]D. R. Price-Williams, "A Study Concerning Concepts of Conservation of Quantities Among Primitive Children," Acta Psychologica, 18:297-305, 1961.

[43]M. Woodward, "The Behavior of Idiots Interpreted by Piaget's Theory of Sensory-Motor Development," British Journal of Educational Psychology, 29:60-71, 1959.

sensory-motor period. Lovell and Slater[44] worked with mental retardates and showed the validity of the developmental stages described by Piaget. Wohlwill[45] carried out scalogram analyses and showed that Piaget's stages do, in fact, form a genuine developmental progression. An explanation of the meaning and procedures used in scalogram analyses is presented by Flavell[46] in his text. In each of these studies Piaget's original ordering of stages was confirmed.

The literature revealed only one study that failed to confirm Piaget's basic ordering of stages. That was a study by Estes[47] done in the mid-1950's. Both Flavell[48] and Dodwell[49] raised questions about the imprecision of the descriptions of techniques used in the study and, in general, cast serious doubts on the results of this study.

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[44]K. Lovell and A. Slater, "The Growth of the Concept of Time: A Comparative Study," Journal of Child Psychology and Psychiatry, 1:179-190, 1960.

[45]Joachim Wohlwill, "A Study of the Development of the Number Concept by Scalogram Analysis," The Journal of Genetic Psychology, 97:345-377, 1960.

[46]Flavell, op. cit., p. 364.

[47]B. W. Estes, "Some Mathematical and Logical Concepts in Children," The Journal of Genetic Psychology, 88:219-222, 1956.

[48]Flavell, op. cit., p. 383.

[49]Dodwell, loc.cit.

<u>Studies Concerned with Concrete Operations and Conservation</u>.--A large part of the research related to Piagetian theory has dealt with concrete operations, and more specifically, with the concept of developing conservation. Experiments pertinent to the present study involve the following areas: (1) confirming the validity of conservation as a concept; (2) affirming the three stages, non-conservation, transition, and conservation, in the development of conservation; and (3) elucidating and testing factors believed significant for inducing the operational stage.

<u>Studies Confirming the Validity of Conservation</u>.--Using 175 American children in kindergarten through sixth grade Elkind[50] conducted a series of experiments devoted to a systematic replication of Piaget's findings on conservation of quantity, weight, and volume. His results showed that the number of conservation responses varied with age level and type of task. The results were "in close agreement with Piaget's findings of a regular, age related order in the discoveries of mass, weight, and volume."[51]

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[50]David Elkind, "Children's Discovery of the Conservation of Mass, Weight, and Volume: Piaget Replication Study II," <u>The Journal of Genetic Psychology</u>, 98:219-227, 1961.

[51]<u>Ibid</u>., p. 219.

Lovell and Ogilvie[52,53,54] tested British children along the lines initiated by Piaget. Using standardized presentations, these investigators tested 322 children on conservation of quantity tasks; 364 children on conservation of weight tasks; and 191 children on conservation of volume tasks. They were able to confirm Piaget's findings on conservation of quantity, weight, and volume.

Uzgiris[55] studied the influence of a variety of test materials on the attainment of conservation. A scalogram analysis of 120 grade school children, twenty from each of the first six grades, indicated that conservation was achieved in the order (1) quantity, (2) weight, and (3) volume on each of the materials involved.

Kooistra[56] used ninety-six children aged four through seven to investigate the effects of five variables: age, sex, content, type of conservation, and form of

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[52]K. Lovell and E. Ogilvie, "A Study of the Conservation of Substance in the Junior School Child," The British Journal of Educational Psychology, 30:109-118, 1960.

[53]K. Lovell and E. Ogilvie, "A Study of the Conservation of Weight in the Junior School Child," The British Journal of Educational Psychology, 31:138-144, 1961.

[54]K. Lovell and E. Ogilvie, "The Growth of the Concept of Volume in Junior School Children," The Journal of Child Psychology and Psychiatry, 2:118-126, 1961.

[55]Ina Uzgiris, "Situational Generality of Conservation," Child Development, 35:831-841, 1964.

[56]William Kooistra, "Developmental Trends in the Attainment of Conservation, Transitivity, and Relativism

conservation of quantity on the attainment of conservation. All the subjects were of superior intelligence, 135 and above. It was found that age, type of conservation, and form of conservation of quantity were significant to attainment of this concept. These results were felt to be in close agreement with Piaget's theory.

Smedslund[57] replicated the work of Piaget on conservation of quantity and weight and verified the sequence of acquisition of conservation. He found somewhat earlier transition ages in his group of children than had Piaget.

McRoy[58] studied the attainment of conservation of quantity, weight, and volume. As in other studies, volume appeared to be the last of the conservation abilities the child acquired. The invariant order of attainment of quantity and weight could not be verified in this study. It should be noted that this last finding was in direct contrast not only to Piaget's theory but to the

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in the Thinking of Children: A Replication and Extension of Piaget's Ontogenetic Formulations," Dissertations in Cognitive Processes--Abstract (Detroit: Wayne State University, 1964).

[57]Jan Smedslund, "The Acquisition of Conservation of Substance and Weight in Children," Scandanavian Journal of Psychology, 2:71-84, 1961.

[58]James McRoy, "A Study of the Development of the Concept of Quantity by Scalogram Analysis," Dissertation Abstracts, 28:1231-B, No. 3, 1967.

replication studies of Elkind,[59] Lovell and Ogilvie,[60] and Smedslund.[61]

Affirmation of the Three Stages of Conservation.--The three stages of conservation described by Piaget were non-conservation, transition, and conservation. A careful qualitative and quantitative study of these stages was made by Lovell and Ogilvie.[62]. They used 322 boys and girls in a junior school in a town in Northern England. They systematically traced the development of the concept of invariance of substance (quantity). The procedure used was similar to that developed by Piaget. Two equal size balls of plasticine were shown to each child. One ball was then deformed by rolling it into a sausage shape as the child looked on. The child was then asked about the amount of plasticine in the ball as compared to the sausage. According to Lovell and Ogilvie, the results of this experiment closely agreed with Piaget's findings:

> Strong evidence has been produced in support of the three stages proposed by Piaget, and in our view, he was justified in trying to trace the development of the concept of invariance of substance. But the stages are not clear cut; the borders between them are zones not lines.[63]

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[59]Elkind, loc. cit. [60]Lovell and Ogilvie, loc. cit.

[61]Smedslund, loc. cit.

[62]Lovell and Ogilvie, "A Study of the Conservation of Substance . . . ," op. cit.

[63]Ibid.

Elkind's[64] replication study of conservation of quantity, mass, and volume produced affirmative evidence concerning the stages described by Piaget. Elkind was able to discern patterns in children's reasoning that helped him in placing a child at a particular stage of conservation development. For example, children who were non-conservers reported two kinds of explanations for their answers. These were: (1) Romancing, it's more because "My Uncle said so"; and (2) Perceptual, "It's more because it's longer, thinner, wider, thicker." Children who were conservers also gave two types of answers: (1) Specific, "That hot dog is longer but thinner so the same"; and (2) General, "No matter what shape you make it into it won't change the amount."

Smedslund[65] affirmed the three stages in the development of conservation in a study involving five to seven year old sons and daughters of delegates to the international committees and organizations in Geneva, Switzerland. He was able to identify the three stages and except for earlier age of acquisition of these stages found the results in close qualitative agreement with those of Piaget.

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[64] Elkind, op. cit., pp. 224-226.

[65] Smedslund, loc. cit.

Almy, Chittendon, and Miller[66] conducted a cross-sectional and longitudinal study designed primarily to validate the development of the child's understanding of the principle of conservation. Two New York City elementary schools, one from a middle-class neighborhood, and the other from a lower-class neighborhood were selected for this study. For the longitudinal study, forty-one kindergarten children were selected at random from the middle-class school and twenty-four kindergarten children were selected from the lower-class school. They were tested at six month intervals for two years for conservation ability on three Piagetian tasks. Both the stages and the order of conservation development suggested by Piaget were affirmed by this part of the study. For the cross-sectional study, 245 children were selected from kindergarten through second grade, and from middle-class schools. These children were tested to determine the extent of their understanding of conservation. Trends in both the middle-class and lower-class schools conform to Piaget's theory. The researchers had expected slower progress in the low socio-economic school, and this was confirmed in the study.

Studies Concerned with Factors Related to Stage Acquisition.--Piaget[67] suggested that four factors affect

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[66]Almy, Chittendon, and Miller, op. cit., pp. 65-110.

[67]Piaget, "Development and Learning," op. cit.

the acquisition of concrete operations. These were: maturation, experience, social transmission, and self-regulation.

From an experimental point of view, maturation and self-regulation have received relatively little attention. By contrast the experience factor has received great attention from researchers trying to induce higher levels of developmental growth. This factor is readily manipulated and measurements in terms of acquisition of higher levels of thinking can be obtained.

Churchill[68] attempted to measure the affects of various experiences on developmental growth. Matched groups of children served as subjects. The treatment group was pre-tested, given experience with seriation, matching, ordering, comparing, grouping, and invariance of numerical relations. They were then post-tested using Piagetian-type tasks. The control group was given a pre-test and the post-test only. The treatment group showed highly significant improvement over the control group in the number of questions answered correctly at the operational level.

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[68]Eileen Churchill, "The Number Concepts of the Young Child: Part 2," Researches and Studies, Leeds University, 18:28-46, 1958.

Wallach, Wall, and Anderson[69] measured conservation of number in 56 six and seven year old children exposed to various kinds of experiences. One group of children was given experience in ignoring irrelevant cues and experience with reversibility. Another group was exposed to a procedure of adding or taking away quantities. Children who both recognized reversibility and ignored irrelevant cues showed a higher rate of conservation than the other children in this study.

Sigel and Roeper[70] noting the failure of studies that attempted to induce conservation directly, selected a number of mental operations believed crucial for the acquisition of concrete operations and conservation. They provided a group of five mentally superior children with experiences involving the mental operations of multiple classification, multiple relationality, atomism, reversibility, and seriation. These children were pre-tested and post-tested for conservation of quantity, weight, and volume. The authors reported:

> Of the training group, four out of the five children were retested and each one of these children showed an increase in the ability to handle conservation tasks after the training period.[71]

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[69] Lise Wallach, Jack Wall, and Lorna Anderson, "Number Conservation: The Roles of Reversibility, Addition, Subtraction, and Misleading Perceptual Clues," Child Development, 38:425-442, 1967.

[70] Sigel and Roeper, op. cit., p. 5.

[71] Ibid., p. 30.

A second small group of intellectually superior children was given only the pre- and post-test. Only one child showed any change in the ability to handle conservation. As a result Sigel and Roeper concluded:

> The results of the explorations reported here support the theoretical position that the training of the children in the prerequisites of particular stages enables the acquisition of the subsequent stage. Thus, the cognitive structure comes into being by virtue of these pre-training experiences. This indicates the interdependence between the stage and its precursor as the Piagetian theory would hold. If this is true, it suggests that the rate of development can be modified and/or accelerated by providing opportunities for the child to acquire the precursors.[72]

Rosenbloom[73] attempted to accelerate children's achievement of concrete operations in a school setting. Using kindergarten children, he attempted to provide them with experiences that would enable them to visualize the result of inverse operations. Materials used for this study came from one of the current elementary science projects, The Minnesota Mathematics and Science Teaching Project (Minnemast). It was found that, "Children who had studied the Minnemast materials were significantly better than the control group of

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[72] Ibid., p. 29.

[73] Paul Rosenbloom, "Implications of Piaget for Mathematics Curriculum," in Improving Mathematics Education for Elementary School Teachers, by W. Robert Houston, editor (East Lansing, Michigan: Michigan State University, 1967), Section II, pp. 44-49.

kindergarteners who had studied in conventional programs. . . ."[74] Over twice as many children in Minnemast, as compared with conventional programs, had attained conservation concepts by the end of kindergarten.

Almy and Dimitrovsky[75] conducted a three year longitudinal study on the affect of systematically designed science and mathematics experiences on developmental growth. The experiences of some of the children were carefully controlled by the dictates of the science and mathematics program used. The experiences of the others was less systematized. All of the children were tested for conservation ability in both the first and the second grades. Although analysis of all the data was incomplete as of March 1, 1968, some general trends were detected by the investigators. More first graders in the study who had had experiences in classifying and ordering as part of the systematized science and mathematics program conserved than the other first graders in the study. By the end of the second grade, however, there were no apparent differences in conservation ability between the two groups of children. The children in the less systematized science and mathematics program had taken

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[74] Ibid., p. 48.

[75] Millie Almy and Lilly Dimitrovsky, "Science and Mathematics Instruction in Kindergarten and First Grade: Outcomes in Logical Thinking in Second Grade" (New York: Teacher's College, 1968), p. 7. (Mimeographed.)

approximately one year longer to reach the concrete operational stage than the children who had had the more highly structured program. On the basis of this preliminary information it appeared that systematic experiences in classifying and ordering materials served to accelerate acquisition of concrete operations.

Coxford[76] tested a group of sixty children at the University of Michigan Laboratory School for conservation ability. Non-conservers and children in transition were given experiences in serial ordering, serial correspondence, and ordinal correspondence. It was hoped that children could advance at least one stage as a result of these experiences. It was found that children who were in the transition stage and were given the requisite experiences made significant gains over transition stage children who were not given any of these experiences. There were no differences between non-conservers who were given practice in seriation and ordination and non-conservers who were given no practice. This study appears to reinforce Piaget's contention that both maturation and experience are significant factors in accelerating or inducing more advanced stages of thinking.

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[76]Arthur Coxford, "Effects of Instruction on the Stage Placement of Children in Piaget's Seriation Experiments," Arithmetic Teacher, 11:4-9, January, 1964.

Muktarian[77] used five and six year olds to show that experiences focused on developing an understanding of logical permanence enabled children to conserve quantity.

Bruner[78] reported that children needed experience in labeling identity in order to accurately judge equivalence. An experiment was conducted in which a quantity of water was moved from one "lake" to another "lake" of different spatial configuration. Six out of ten non-conservers reported that after the water was transfered to the second "lake" it was not the same water that had been in the first "lake." On the other hand, conservers identified the water in both "lakes" as being the same water and consequently the same amount. Experiences designed to point out the "sameness" of objects that undergo spatial or figural reorientations proved successful in inducing conservation.

Children who were not helped by Bruner's identity experiences were found, six out of seven times, to be focusing on a single perceptual feature. He pointed out:

> If they could be shielded from a quick, misleading ikonic rendering of the situation-shielded in a fashion that would permit them to represent the situation in language before

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[77]Herbert Muktarian, "A Study of the Development of Conservation of Quantity," Dissertation Abstracts, 27: 2508-2509, No. 7-B, 1967.

[78]Bruner, "On the Conservation of Liquids," op. cit., pp. 168-182.

> they see it--perhaps the language would serve as a guide for organizing their perceptions in a new way.[79]

Using a series of beakers of varying sizes, four to seven year old children were given experience in estimating the height of a column of water poured from one beaker to another behind a screen, and in front of the screen. They were asked to verbalize what was happening as well. The screening procedure helped the older children to separate perceptual evidence from judgments. The younger children continued to judge quantity on the basis of imagined perceptual equality.

The significant feature of Bruner's work, from the standpoint of the present study, is the fact that experiences were delineated that resulted in stage induction. In the sampling used by Bruner and his associates, fifty-five per cent of the six and seven year olds conserved on the pre-test. After the treatments described above, over ninety per cent of the six and seven year olds conserved.[80]

It should be noted that some degree of success in accelerating stage acquisition has been claimed in each of the preceding investigations. Although Piaget has stated that experience alone is insufficient to promote accelerated developmental growth, the evidence seems to indicate that experiences involving such skills and

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[79] Ibid., p. 193.

[80] Ibid., p. 196.

understandings as ordering, matching, grouping, recognizing the invariance of numerical relations, ignoring irrelevant cues, decentering, visualizing results of inverse operations, reversibility, multiple classification, multiple relationality, and atomism do in some way accelerate the rate of intellectual development.

Piaget's fourth, and last, factor affecting the acquisition of developmental stages was social transmission. Piaget considered social transmission to be linguistic or educational transmission wherein the child received valuable information as a result of adult-directed instruction. It seemed that this factor was very closely related to the experience factor. The chief difference was that Piaget considered experience to involve direct confrontation with and manipulation of an object by the learner. Social transmission implied that the learner was in a more passive state and received knowledge by means of language from an adult or a peer. A number of studies have been designed ostensibly to investigate the affects of social transmission on developmental growth.

Mermelstein and Shulman[81] studied the affects of formal schooling on the performance of six and nine year

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[81] Egon Mermelstein and Lee Shulman, "Lack of Formal Schooling and the Acquisition of Conservation," Child Development, 38:39-52, March, 1967.

old children on Piagetian conservation tasks. They also investigated the affects of language on a child's ability to conserve. Sixty children from Prince Edward County, Virginia, an area that had been without public schools for four years prior to the investigation, were involved in this study. In addition, a matched group of sixty six and nine year old children from a similar community that had had school regularly were studied. It was found that on Piagetian conservation tasks no differences existed between six year olds in Prince Edward County and six year olds from the community which had had regular schooling. It was further found that on verbal and non-verbal tasks no differences existed between Prince Edward County nine year olds and nine year olds from the other community. Apparently a lack of formal schooling had had no affect on a child's ability to conserve. In the older group of children, language did not seem to be a factor in determining conservation ability. These findings tend to indicate that stage development takes place despite an interruption in social transmission.

Mermelstein and Meyer[82] studied the effectiveness of a number of conservation training techniques to ascertain their effect on certain populations. Using 316 three to six year old children, the investigators

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[82]Egon Mermelstein and Edwina Meyer, "Conservation Training Techniques and Their Effects on Different Populations" (address at Convention of American Educational Research Association, February 8, 1968).

employed cognitive conflict, language activation, verbal rule instruction, and multiple classification training techniques to induce the concept of conservation of quantity. It was found that conservation was not induced by any of the training procedures in any of the populations.

Smedslund,[83] carried out a series of investigations of children's acquisition of conservation of quantity and weight. He used five to seven year old Norwegian children as subjects. The first experiment involved external reinforcement methods. One group of sixteen children was allowed to observe empirical conservation of weight on a balance. A second group of sixteen children practiced on addition and subtraction of quantities of material on a scale. A third group of sixteen children served as a control. Smedslund found no differences in conservation acquisition among the three groups. External reinforcement techniques had not induced stage development.

Another experiment by Smedslund involved practice in conflict situations without external reinforcement.

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[83]Jan Smedslund, "The Acquisition of Conservation of Substance and Weight in Children I," Scandanavian Journal of Psychology, 2:11-20, 1961; Jan Smedslund, "The Acquisition of Conservation of Substance and Weight in Children II," Scandanavian Journal of Psychology, 2:71-84, 1961; Jan Smedslund, "The Acquisition of Conservation of Substance and Weight in Children III," Scandanavian Journal of Psychology, 2:85-87, 1961; Jan Smedslund, "The Acquisition of Conservation of Substance and Weight in Children IV," Scandanavian Journal of Psychology, 2:153-155, 1961; Jan Smedslund, "The Acquisition of Conservation of Substance and Weight in Children V," Scandanavian Journal of Psychology, 2:156-160, 1961; Jan Smedslund, "The Acquisition of Conservation of Substance and Weight in Children VI," Scandanavian Journal of Psychology, 2:203-210, 1961.

Thirteen children, ages five and six, were given practice sessions in which simultaneous deformations of clay and surreptitious addition or subtraction of some clay material resulted in a change in quantity different from what was expected by the child. Four out of the thirteen children changed from no trace of conservation in a pre-test to several correct answers after three training sessions. The final experiment in this series involved practice on continuous and discontinuous materials in problem situations without external reinforcement. A total of 154 children, ages five to seven, were given practice with adding and subtracting material from both continuous and discontinuous objects. The number of children who acquired conservation of quantity was largest after practice with the discontinuous objects.

Although Smedslund's investigations were closely related to the experience factor, their basic objectives were oriented toward educational transmission. These experiments indicated that educational experiences geared toward the presentation of cognitive incongruities affected induction of conservation.

Studies by Gruen[84] and Stuck[85] were conducted in a manner quite similar to that used by Smedslund. Both

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[84]Gerald Gruen, "Experiences Effecting the Development of Number Conservation in Children," Dissertation Abstracts, 25:6751, No. 11, 1965.

[85]Gary Stuck, "A Comparison of the Effect of Equilibration Theory and S-R Theory-Based Training on Acquisition of Permanence of Conservation of Weight," Dissertation Abstracts, 27:2899-A, No. 9, 1967.

investigators were concerned with educational methods that might be successful in accelerating stage development. Both concentrated on cognitive incongruities and reinforcement techniques. Only Gruen found cognitive incongruity methods to produce greater acceleration. On the whole Piaget's social transmission factor has experienced neither the breadth of coverage nor the success in stage induction that the experience factor has.

Summary.--To summarize the review of literature, the following statements relative to Piaget's basic theory are considered both accurate and appropriate by the writer. First, Piaget and others have developed a stage-related theory that describes a child's intellectual growth from birth to age fifteen. Second, according to this theory, the onset of concrete operations is a very significant occurrence in the intellectual development of young children. Third, achievement of conservation is a useful indicator of a child's developmental growth. The child who conserves is considered to operate at the concrete operational stage. Both the acquisition of the various skills and the stages of conservation development as described by Piaget and his co-workers have been confirmed. Fourth, induction of concrete operations is possible if conditions that enable basic intellectual structures to develop into necessary complex structures are established. The factors that affect the conditions have been delineated by Piaget and others.

In addition to statements of basic theory, research relevant to each of the theoretical statements was presented in this chapter. Studies by Peel (38), Dodwell (39), Hood (40) Goodnow (41), Price-Williams (42), Woodward (43), Lovell and Slater (44), and Wohlwill (45) demonstrated the validity of Piaget's stage-related theory. Both the descriptions and the order of stages were shown to be efficacious by these studies. Investigations by Lovell and Ogilvie (52, 53, 54), Uzgiris (55), Kooistra (56), and Smedslund (57) confirmed the validity and order of acquisition of conservation of quantity, weight, and volume. Only the study by McRoy (58) cast any doubt on the order of acquisition of these concepts. Three stages in the achievement of conservation were confirmed in the studies by Lovell and Ogilvie (62), Elkind (50), Smedslund (57), and Almy (66). Studies by Churchill (68), Wallach (69), Sigel and Roeper (25), Rosenbloom (73), Almy and Dimitrovsky (75), Coxford (76), Muktarian (77), and Bruner (78) showed that certain experiences caused accelerated achievement of concrete operations as measured by a child's ability to conserve quantity.

On the basis of the studies reviewed it appeared that the experience factor has been more instrumental in producing accelerated developmental growth than Piaget believed possible. While the evidence has not been incontravertible, there has accumulated over the past ten years sufficient quantities of evidence to warrant continued investigation into the area of acceleration of concrete operations.

CHAPTER III

IMPLEMENTATION OF THE STUDY

This chapter describes the organizational plan of the study, the methods and materials used with each group of pupils, the evaluative instruments, and the methods of collecting data. A summary of the hypotheses tested and models used in analyzing the data collected in the study are also included.

Background of the Study.--During the summer of 1967, the superintendent of schools in Okemos, Michigan, contacted personnel of the Science and Mathematics Teaching Center at Michigan State University concerning the possibility of using one of the newer science programs in an Okemos School. Dr. Glenn Berkheimer, coordinator of the Michigan State University Trial Center for SCIS, invited the writer to design a study that would involve the use of SCIS methods and materials in the Okemos School District. As a result of the request, the present study was designed by the writer.

A meeting was held during the first week of September, 1967, with administrative personnel of the Okemos Public School System. At this meeting the writer pointed out the possibility and the value of conducting research related to the intellectual development of young children resulting from certain science experiences. It was proposed that the school district purchase and use SCIS materials in half of the first grade classes in one elementary school in Okemos and the rest of the first grade pupils in that school have the usual science program. Developmental growth of all of the first grade children in that school would be measured using a series of Piagetian conservation tasks as evaluative criteria. The proposal was found to be acceptable and a subsequent meeting was held at which the proposal was presented to the principal of the Cornell School, Okemos, Michigan. He found the study acceptable and arranged a meeting between the writer and the four first grade teachers at the Cornell School. The purpose of the meeting was to present the study for the teachers' consideration and to determine their willingness to actively participate in the study. The meeting with the teachers was held in mid-September at the Cornell School. All four teachers agreed to participate. The study was initiated at the Cornell School on January 3, 1968.

General Design of the Study.--This study was carried out in three first grade classes and one first-second grade transition class in the Cornell School, Okemos, Michigan. A total of eighty-seven children were enrolled in these four classes when the study began. The study was initiated on January 3, 1968 and was terminated on May 6, 1968, a total of eighteen weeks.

The Community.--Okemos is a small suburban community located about ten miles east of Lansing, Michigan. Families of private businessmen, company executives, and college faculty members make up the bulk of Okemos' inhabitants.

At present the Okemos School District is made up of three elementary schools--Edgewood, Wardcliff, and Cornell Schools, one junior high school, and one senior high school. Cornell School, which is located at the eastern boundary of Okemos, draws about one-fourth of its student population from surrounding rural areas, and the remainder of its students from the more affluent local neighborhoods.

The Children.--The ages of the children participating in this study on January 1, 1968 ranged from six years one month to eight years eleven months with an average age of six years ten months. Approximately fifty per cent of these children came from families in which the average annual income exceeded fifteen thousand dollars. About one-fourth of the fathers of these children had earned a Master's Degree, a Doctor of Philosophy Degree, or a Medical Degree. Sixty per cent of the fathers and approximately fifty per cent of the mothers had earned Bachelor's Degrees.

The Classes.--The children in this study were randomly assigned to one of four classes for the purpose of studying science. The names of the forty-seven boys in this group were placed in a hat, withdrawn one at a time and assigned alternately to one of the four classes. The forty girls were randomly assigned in a similar manner. Thus each of the classes consisted of ten girls and either eleven or twelve boys. Two of the classes had been arbitrarily designated as the experimental group by the investigator and two classes as the control group prior to the random assignment of pupils. The experimental group studied science by means of the methods and materials contained in an SCIS unit entitled Material Objects.[1] The control group studied science by means of the usual first grade science program. The text used for the control group was Science is Fun.[2]

Table 2, on page 63, is a summary of the make-up of the four science classes involved in this study.

The Teachers.--After all of the children were randomly assigned to the four science classes, the principal of Cornell School arbitrarily assigned each of the four

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[1]Material Objects (Boston: D. C. Heath and Company, 1966).

[2]Wilbur Beauchamp, Science is Fun (Chicago: Scott Foresman and Company, 1961).

TABLE 2.--Composition of the four first grade science classes in the Cornell School.

Group	Number of Pupils		Age Range	General Design		
	Boys	Girls		Pre-test	Treatment	Post-test
A	12	10	6-4 to 8-11	Yes	SCIS	Yes
B	12	10	6-4 to 8-9	Yes	SCIS	Yes
C	12	10	6-2 to 8-1	Yes	Scott Foresman	Yes
D	11	10	6-1 to 8-11	Yes	Scott Foresman	Yes

teachers to one of the classes. The randomization of students and assignment of teachers was completed before December 1, 1967.

On December 7, 1967 the investigator met with the four teachers involved in the study for the purpose of outlining the general procedures for the study. At this meeting all of the teachers were oriented to the following aspects of the investigation:

1. A brief description of the design; reasons for randomizing students; methods of pre-test, post-test observations, and general procedures for instruction, teacher preparation and feedback.
2. Availability of materials, equipment and technical assistance for the control group teachers.
3. Establishment of separate meeting dates for experimental and control group teachers to discuss specific

aspects of each program.

4. Understanding that no communication between control and experimental group teachers take place concerning their respective programs.

At a meeting on December 16, 1967 with the two experimental group teachers, the investigator discussed the following topics:

1. Objectives of science in the elementary school as envisioned by the investigator.
2. Specific details about the SCIS program including historical development, goals, types of material available, specific lessons, difficulties encountered by other teachers, need for evaluation, text to be used, and availability of technical assistance.

At a meeting with the two control group teachers on December 18, 1967, the following topics were discussed:

1. Objectives of science in the elementary school.
2. Specific information relevant to the science program to be conducted, materials and equipment available through the Science and Mathematics Teaching Center at Michigan State University, choice of first units to be taught, and agreement by both teachers to cover the same topics, but to maintain autonomy as to the style of presentation.

Methods and Materials.--In order to provide equal time for science instruction in both the experimental and control groups, all science lessons were conducted for thirty minutes per day and three days per week. The children moved from their usual classroom to their science classroom in a manner similar to that in a departmentalized junior high school. After the science period was completed the children returned to their regular classrooms.

Experimental Group.--The lessons and related experiences presented to the experimental group were carefully delineated in the teacher's guide that accompanied the equipment for the Material Objects[3] unit. The overall goals of the unit were stated as follows:

> While dealing with material objects in this unit the child will develop various attitudes, abilities and skills, including habits of careful observation, a vocabulary that is useful in describing objects, methods of recording observations and experiences, and the ability to discriminate fine differences and to recognize broad similarities.[4]

Two kinds of lessons were stressed in this unit. These were "invention lessons," involving activities of defining new concepts, and "discovery lessons," designed to let a child manipulate materials, broaden his background of experience and apply new ideas. It was assumed that the experimental group teachers closely followed the directions and recommended activities in the teacher's guide that accompanied this unit.

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[3] Material Objects, op. cit.

[4] Ibid., pp. ix-xi.

The Material Objects unit was arranged in the following schematized sequence. Lessons that are starred (*) are invention lessons. All others are discovery lessons.

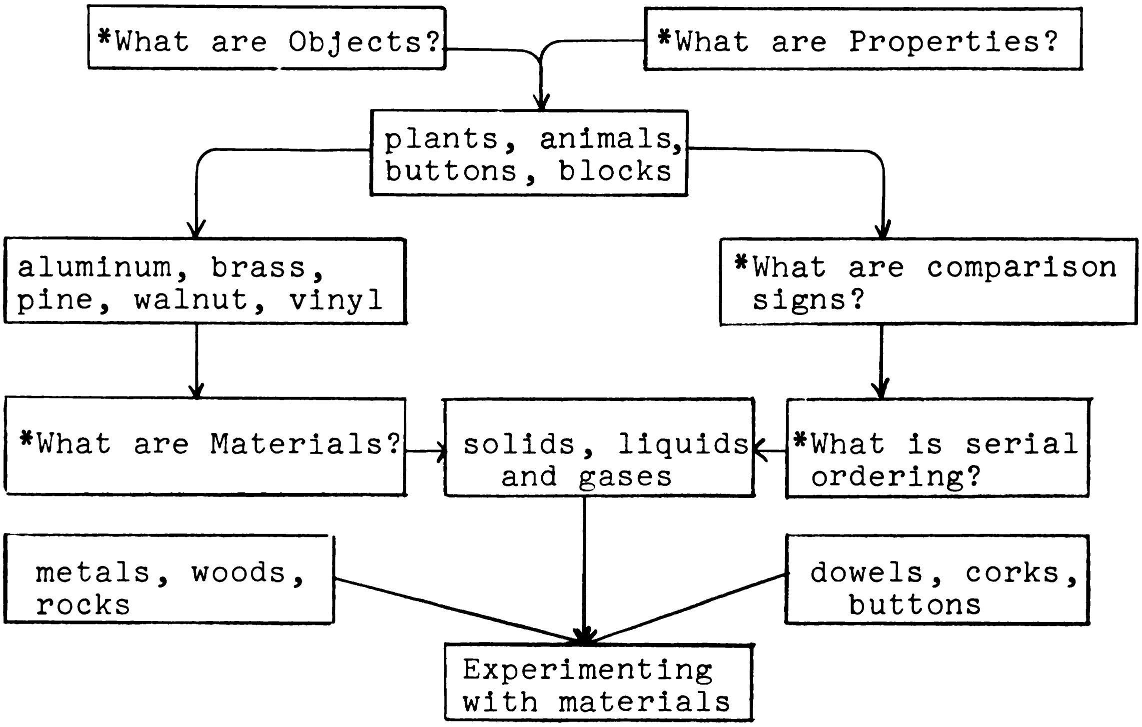

Figure 1.--The sequence of topics taught in the Material Objects unit to pupils in the experimental group.

The following is a list of lessons[5] in the order in which they were taught in the Material Objects unit:[6]

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[5]Each activity represents approximately thirty minutes of class time.

[6]Material Objects, op. cit.

Part One--Introducing objects and their properties.

Activity 1--Objects in the classroom

Activity 2--Object collections

Activity 3--Object hunt

Activity 4--Observing plants

Activity 5--Observing animals

Activity 6--Grandma's button box

Activity 7--Object grab bag

Part Two--Introducing the concept of material.

Activity 8--Grouping collections of objects

Activity 9--Invention of the concept material

Activity 10-Using the concept of material

Activity 11-Sorting metals and woods

Activity 12-Changing the form of balsa wood

Activity 13-Observing the same material in different forms

Activity 14-Observing and sorting rocks

Activity 15-Observing liquids

Activity 16-Observing gases

Part Three--Comparison and serial ordering.

Activity 17-Inventing comparison of objects using signs

Activity 18-Inventing serial ordering

Activity 19-Comparison of objects using signs

Activity 20-Calico clam shells

Activity 21-Using comparison signs

Part Four--Experimenting with material objects.

Activity 22-Rock candy and lump sugar

Activity 23-Experimenting with liquids and mixtures

Activity 24-Solid and liquid water

Activity 25-Experimenting with air

Activity 26-Experimenting with air and water

In order to provide an example of a typical SCIS lesson for the reader, the following summary of Activity 8, "Grouping Collections of Objects," is presented.[7] Like all of the other Material Object lessons, this activity was divided into five sections. The first section stated the "Objective of the learning experience" in a brief sentence. The second section provided "Background information" for the teacher. Relationships between this activity, past lessons, and succeeding activities were pointed out. A discussion of how to implement the objectives of this lesson with the materials provided was also included in this section. The third section was "Teaching materials." It consisted of a list of all the materials to be distributed to the children. Section four was made up of "Teaching suggestions." A general plan for carrying out this exercise and what to look for in the way of children's behaviors were mentioned. The last section was "suggested use of the student activity pages." The teacher was also told to watch the reactions of the children

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[7] *Ibid.*, pp. 20-21.

as they sorted the materials used with the activity pages since the methods employed by the children would give insight into the child's understanding.

As a result of the experiences and the manipulation of equipment and materials, the child who completed the entire Material Objects unit was assumed to have had experiences with the skills and understandings given in Table 3.

On the basis of the mental operations deemed necessary for achieving concrete operations, the various activities in this unit provided practice in the mental operations indicated in Table 4.

Control Group.--The control group teachers followed the sequence of topics presented in the Scott Foresman Company text, Science is Fun.[8] The following topics were covered in the control group in the eighteen week period during which this study was carried on:

1. Weather.[9] A unit on the weather made up the first part of the text Science is Fun. For this unit the text consisted of twenty-five pages of pictures related to weather and intended to serve as a "springboard" for class discussion. A two page section suggested that weather records be maintained and three pages of suggested experiments concluded the text materials. For the purposes of

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[8]Beauchamp, loc. cit. [9]Ibid., pp. 3-34.

TABLE 3.--Activities and related skills in the SCIS program.[a]

Activity Number	Skill, Understanding
1	Differentiate between an object and the properties of that object.
2, 3, 4	Observe, describe, and sort objects on the basis of their properties.
4, 5	Note similarities and differences among objects.
6	Sort objects on the basis of size, shape, or color.
7	Compare objects having the same properties regardless of their physical configuration.
8	Sort objects by physical properties other than size or shape.
9, 10	Contrast and distinguish objects made of one material from objects made of more than one material; classify objects by materials of which it is composed.
11	Identify similarities and differences among a variety of metallic objects.
12	Identify and sort wood by properties and kind.
13, 14	Identify properties of objects made of the same material but in different forms; realize that an object's form can change while the material remains the same.
14,15,16	Describe properties of solids, liquids, and gases.
17, 19, 21	Use comparison signs to indicate comparing by a property.
18,19,20,21	Arrange objects in a serial order by using comparison signs.
22,24	Recognize that the material of an object may remain the same, even though the object's appearance changes.
22,24	Recognize that two objects may appear to be different but are still made of the same material.

[a]Compiled by the writer.

TABLE 4.--Mental operations related to the various SCIS activities.[a]

Mental Operation	Activity Number
Multiple classification	1, 2, 3, 4, 5, 6, 7, 8 9, 10, 11
Serial ordering	17, 18, 19, 20, 21
Reversibility	22, 23, 24
Multiple relationality	1, 8, 9, 11, 12, 13

[a]Compiled by the writer.

this study, additional materials and information were provided to the control group by the investigator through the facilities of The Science and Mathematics Teaching Center. These materials enabled additional activities to be carried on. A weather station was established. Children were given experiences in identifying clouds and using related weather equipment. A wind vane, anemometer , barometer, thermometer, and rain gauge were available for use in each classroom. Experiments and demonstrations involving evaporation and condensation were performed by teachers and pupils. A weather forecast chart was made.

2. We Move Things.[10] The second unit in the text book dealt with the topics of force and energy. This unit was treated in the text much like the unit on weather. There were eleven pages of pictures

[10]Ibid., pp. 35-52.

designed to stimulate class discussion and five pages of suggested experiments.

The children studied and discussed how animals and other living things move. They discussed the concept of force. Simple machines were demonstrated and children used inclined planes, pulleys, levers, screws, and a wheel and axle to gain an understanding of how these machines function. Magnets were used to demonstrate interaction at a distance and its relation to moving objects.

3. Animals.[11] The third unit of the text dealt primarily with differences and similarities in groups of animals. This was the first unit in the text to present verbal as well as pictorial information. The first eleven pages of the unit stressed differences among animals by presenting a series of pictures of a variety of animals. This was followed by a ten page section stressing similarities among a variety of animals. The last page of this unit was made up of a series of incongruous pictures such as a robin with four legs and a dog with feathers. The children were asked to discover what was wrong with each picture.[12]

In addition to the information about animals in the text, the teachers emphasized eating habits, locomotor organs, and types of coats of various

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[11] Ibid., pp. 53-76.

[12] Ibid., pp. 66-76.

animals by bringing frogs, toads, fish, chicks, kittens, and puppies into the classroom for the children to observe. The two control classes took a trip to the University farms to observe a variety of animals.

The teachers presented filmstrips related to the topics covered in the text. General activities such as drawing pictures related to the topics covered and preparation of small booklets entitled "What I Have Learned" accompanied each of these units.

For the control group, the major difference between the presentation of topics during this study and past presentations of the same topics was the availability of related equipment in quantities sufficient to provide material for all youngsters to study and manipulate. Technical information and manipulative materials were made available for the teachers by the investigator and the Science and Mathematics Teaching Center of Michigan State University. Textbooks were provided for all of the children in each of the two classes by the school district.

The children in the control group received no systematic instruction in the mental operations deemed necessary for acquiring concrete operational thinking. Some lessons provided the child with opportunities to observe and classify and other lessons stressed differences in size or force. On the whole, these children participated in a series of lessons that placed major emphasis on subject matter, not on the skills and processes of science.

Table 5, on page 75, is a summary of the science activities presented to the children in the experimental and the control groups.

Preparation of the Evaluative Instrument.--In order to assess the developmental growth of the first grade children in this study, a means of evaluating the thinking of these children was needed. The work of Piaget and his co-workers involving conservation as a criterion for determining a child's stage of developmental growth provided the assessment means that was needed. Four selected Piagetian conservation tasks were placed on film to give each child as standardized a presentation of visual stimuli as possible. A sound track was tape recorded to provide each child with verbal information about the four filmed tasks. In addition, tape recorded instructions for using a color-coded[13] answer form were prepared. All evaluative materials were developed and field tested in the metropolitan Lansing area during November and December, 1967.

Films.--After reviewing relevant literature, this investigator determined that filmed versions of conservation of liquid quantity, conservation of continuous solid

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[13]All teachers tested the children in their classes to insure that the children knew the colors used in this study by sight and by name.

TABLE 5.--Science activities of the experimental and control groups.

Program	Experimental	Control
	SCIS Material Objects Unit	Scott Foresman Science is Fun--Units 1,2,& 3
Activities	1. Differentiating, describing, sorting, observing objects on the basis of properties. 2. Sorting objects on basis of size, shape, color, or other physical property. 3. Distinguishing between object and material that makes up the object. 4. Identifying and classifying objects and materials. 5. Arranging objects in a serial order. 6. Recognizing that material remains invariant in the face of changes in appearance.	1. Identifying clouds and weather instruments. 2. Defining evaporation and condensation. 3. Predicting weather. 4. Identifying simple machines. 5. Defining force, friction. 6. Experimenting with magnets, levers, pulleys, and inclined planes to learn about mechanical advantage. 7. Distinguishing characteristics and identifying animals. 8. Classifying animals by size, coat, and how young are born.
Processes Stressed	1. Observing 2. Classifying 3. Ordering 4. Hypothesizing 5. Testing 6. Drawing valid inferences and conclusions 7. Making operational definitions	1. Observing 2. Classifying 3. Predicting 4. Defining
Major Emphasis	Process and Content	Content
Length of Program	90 minutes per week 18 weeks	90 minutes per week 18 weeks

quantity, conservation of discontinuous solid quantity and conservation of weight were most appropriate for use with first grade children.

The basic format for each of the four film clips was the same. In each of the films the child was initially shown two objects of equal mass. One of the objects was in some way physically rearranged. The child was then asked to make a judgment about the relative mass of the re-arranged object as compared to the object which had remained untouched. The child had four options. He might choose to believe that the rearranged object had become more massive. He could decide that the rearranged object had become less massive. He might believe that both objects were still of equal mass. Lastly, the child might be uncertain as to the relative mass of the two objects.

For the purpose of producing the necessary films, a script was prepared by the investigator and presented to the head of film production at the Michigan State University Instructional Media Center. Arrangements were made with the Instructional Media Staff to provide technical assistance related to preparation and production of high quality sixteen millimeter films. Scripts used for the final film production were written to meet this investigator's specifications by a staff member of the Michigan State University film production unit.

The four film clips were produced by Capital Film Services, a professional film production firm in Lansing, Michigan, in November, 1967. Lighting, camera angles, length of time for each shot and specific actions were dictated by the script. The films were produced on Kodachrome II stock. A total of two hundred five feet of film was produced. The four film clips were spliced together with black leader film separating each of the clips and were placed on a single reel. Scripts used for the production of the films are found in the Appendix.

Sound Production.--The audio portion of the instrument was prepared on magnetic tape. Information concerning initial quantities of the various substances in each film clip, a question about the quantities of the substances after physical rearrangement had taken place and directions for marking the answer sheets was tape-recorded. A Revere-Wollensak Model 3000 magnetic tape recorder was used both for taping and for play-back in all cases.

Response Form Preparation.--This investigator sought to prepare response forms that (1) required no reading on the part of a child, (2) were simple to use, and (3) which provided no additional or confusing information to a child. To achieve these ends it was decided that all substances used in the four film clips would be colored and that all figures or boxes on the answer form would be colored to match the substances in the film.

Two types of answer forms were initially prepared. One type consisted of scale drawings of the figures or objects actually seen in the film clips. Each figure was colored to match, as closely as possible, the color of the object seen in the film. Stencils of this answer form were prepared, duplicated and colored with Tempera poster paints and felt-tip pens by the investigator. The second type of answer form consisted of four rows of four one-half inch square boxes. There was a separate row of boxes for each film clip. The boxes were colored to match, as closely as possible, the colors of the various objects seen in the film clips. Stencils of this answer form were prepared, duplicated and colored with poster paints and felt-tip pens by the investigator.

Description of the Evaluative Instrument.--Descriptions of the four film clips, the sound track, and the response form are included in this section. A detailed script used to prepare the sound track is included in the Appendix.

Film clip one--conservation of liquid quantity: Two beakers of colored water, one green, the other blue were seen as the film opened. Both beakers contained exactly the same amount of water. The scene changed slightly and a tall, thin cylinder was seen standing next to the two beakers. A hand reached in, took the glass of blue water and poured all of the water into the tall cylinder.

The children were told, by means of a tape-recorded sound track, that the water was colored to help them tell the glasses apart and that there was exactly as much green water as there was blue water. After the blue water had been poured into the cylinder the children were asked if there was more blue water, more green water, or just as much blue water as green water. Directions for marking the answer sheet were then given.

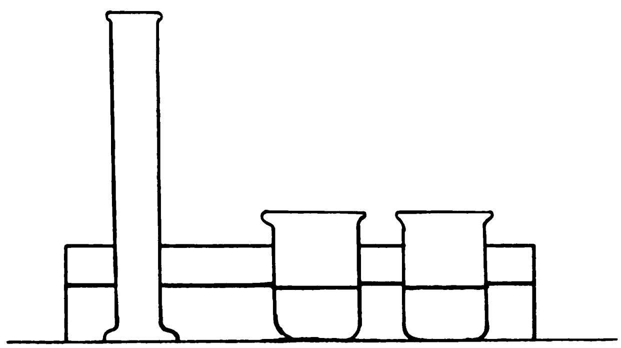

Figure 2.--Beakers and cylinder as they appeared in film clip one.

Film clip two--conservation of continuous solid quantity: Two "pies," one made of red pla-dough[14] and the other of green pla-dough were seen. Both "pies" were the same size, but one had been cut into six slices. A hand reached in and moved the slices of red pie apart.

The audio portion provided the children with the information that the pies were colored to help them tell the pies apart and that there was exactly as much red pie as there was green pie. After the slices of red pie were

[14]Plasticine.

separated, the children were asked whether there was more red pie, more green pie, or the same amount of red and green pie and they were given directions for marking the answer sheet.

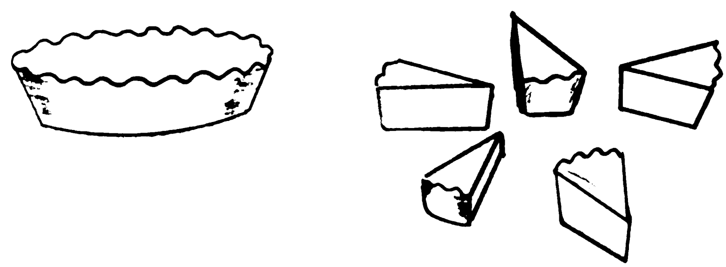

Figure 3.--Pla-dough "pies" as they appeared in film clip two.

<u>Film clip three--conservation of weight</u>: Two equal sized, colored pla-dough balls were placed on a scale one after the other to show that they weighed the same. One ball was then rolled into a sausage shape.

The children were told that the purple pla-dough ball weighed exactly as much as the yellow pla-dough ball. After the purple ball was rolled into the sausage shape, the children were asked about the relative weights of the ball and the sausage and given directions for marking the answer sheet.

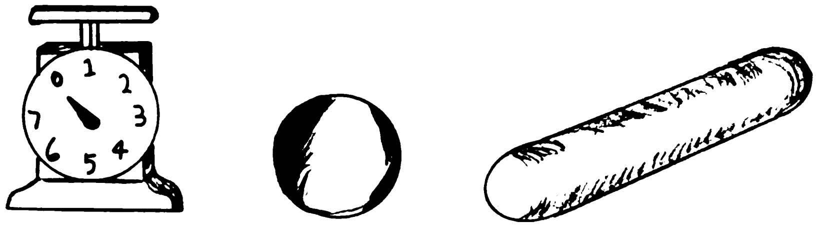

Figure 4.--Scale and pla-dough shapes as they appeared in film clip three.

Film clip four--conservation of discontinuous solid quantity: Two buildings, one made of red bricks and the other of blue bricks, were seen. Both buildings were long and low and exactly the same size. A hand reached in and rearranged the bricks in one of the buildings to make that building tall and thin--a "skyscraper." The children were told that there were exactly as many red bricks as there were blue bricks. After the red bricks were rearranged, the children were asked if there were more red bricks, blue bricks, or the same number of bricks, in the respective buildings and they were, again, given directions for marking the answer sheet.

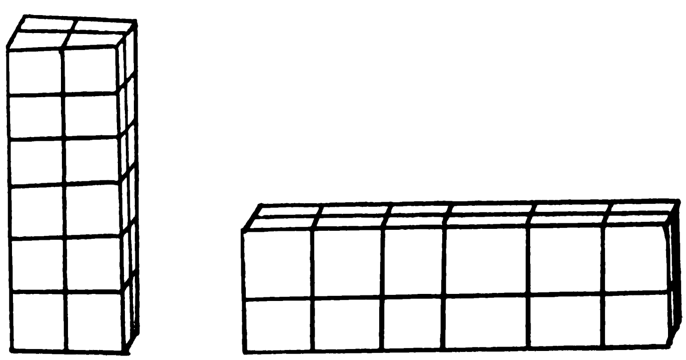

Figure 5.--Block "buildings" as they appeared in film clip four.

The data in this study were collected by means of the responses of the first grade children to the four conservation tasks. For the purpose of collecting the data, special answer forms were prepared by the investigator. All of the children's written responses were marked on this color-coded answer sheet. The answer sheet was made up of a series of sixteen one-half inch square boxes. The colors of the various boxes corresponded to the colors of the objects seen in the films. Copies of the answer forms are included in the Appendix.

Methods of Collecting Data.--In order to collect the data for this study, group testing procedures that were reliable, valid and convenient for use in the schools were needed. For the purposes of this study, testing procedures were considered reliable and valid if the testing conditions were replicable for each observation and if the children in the groups were unable to communicate with one another during the testing session. The procedures were considered convenient if they upset the usual classroom routine as little as possible and caused minimum relocation of classes or school facilities.

The library at the Cornell School was used as a screening room. Based on the size of the library and the number of children involved in the study, the investigator determined that if ten children at a time were tested, reliability, validity and convenience could best be maintained.

The pre-test and post-test observations of the children were carried on according to the following format:

Children in groups of ten were taken from their classrooms and brought to the school library. Chairs and tables were set up in the library in a way that would allow all children to have an unobstructed view of the screen, and at the same time, prevent the children from seeing each others' answers. To prevent the children from seeing answer sheets other than their own, cardboard partitions were fashioned and placed on each table between the pupils.

At the first session of both the pre-test and the post-test, children were permitted to sit at any desk where there was an answer sheet. They were asked to remember that location and to sit in that same place at the next session. The pre-test was conducted in two sessions on consecutive days. In a similar fashion, the post-test was also conducted in two sessions on consecutive days. At the start of the first session children were given a five minute training period on the use of the answer sheet. A detailed description of the training period is included in the Appendix.

The children were then shown the first two film clips, Conservation of Liquid Quantity and Conservation of Continuous Solid Quantity, answers were marked, and the children were returned to their classes. No information on the correctness of choices was given at any of the sessions. An assistant was present at each session to help children who had problems, to observe the children's behavior, to insure that only one box on a line on a child's answer sheet was circled, and to assist with the distribution and collection of materials.

The procedures of the second session followed the procedures of the first session very closely. Children were reminded to sit in the same places they had sat the day before. A two minute review of how to use the answer sheet was given. This was followed by the showing of film clips three and four, Conservation of Weight and Conservation of Discontinuous Solid Quantity.

A make-up session was held for all children who were absent on the days their group was tested. The format of the make-up sessions followed that of the regular sessions exactly.

For the purpose of evaluating the children's answers the following criteria were used:

If a child circled either of the first two colored boxes on a line, the child was considered a non-conserver. If a child circled the white box on a line, he was considered a conserver. By circling the orange box on the line the child indicated that he was in the transition stage.

Hypotheses and Models Used to Test the Hypotheses.-- In order for the investigator to assess a child's attainment of concrete operations, children in both the experimental and control groups in this study were pre-tested and post-tested for the ability to conserve weight and quantity. After collecting the post-test data the results were compiled and analyzed. It was the opinion of the investigator that the type and the limited quantity of data collected on each child justified the need for a more rigorous rejection level. Consequently, null hypotheses were rejected when it was found that results occurred by chance no more than two times in one hundred. The following is a compilation of research hypotheses formulated for the study and the statistical hypotheses used for testing data:

In hypothesis one of this study, it was predicted that children who studied science by means of SCIS methods and materials would score higher on a test of conservation of quantity than children who had the usual science program. Conservation of quantity data were compiled by using a composite of answers reported by the child on film clips one, two, and four. Children received two points for each white box circled, one point for each orange box circled, and zero points for any other boxes circled on each task. Thus a child could score from zero to six points in this way. Zero represented complete non-conservation; six represented complete conservation; and one through five points represented incomplete conservation--or, as it is called, transition.

The model used for analyzing data related to hypotheses one and two was analysis of covariance. When the study was initially designed, the investigator proposed using a two way analysis of variance for the purpose of analyzing the data in hypotheses one and two. However, after the post-test was administered and the data analyzed it was found that, despite random assignment of pupils to treatment and control groups, there appeared to the investigator to be larger mean differences on the pre-test than expected. In order to take into account differences among the groups on the pre-test, it was decided that analysis of covariance be used in testing the data.

For computing the analysis of covariance the pre-test served as the covariate and the analysis was made on treatment effects, sex effects, and interaction effects. It was noted by the investigator that analysis of covariance was useful for testing the significance of data only when there were equal numbers of cases in each cell. In this study there were eighteen girls in the control group, nineteen girls in the experimental group, twenty-one boys in the control group, and twenty-two boys in the experimental group. Therefore, a certain number of children were randomly deleted from the analysis of data in each sub-group, with the exception of the control group girls.

After all data were collected the names of the boys in the experimental group were placed on slips of paper. The slips of paper were placed in a hat and four slips were withdrawn. The data on these boys were deleted from the analysis. A similar procedure was carried out to randomly delete that data on three boys from the control group, and one girl from the experimental group. Then the analysis of covariance was carried out. Results of this and all other analyses is reported in Chapter IV.

By means of hypothesis two it was predicted that girls would score higher than boys on a test of conservation of quantity.

One of the investigator's concerns in this study was with differential acquisition of conservation of quantity by boys and girls. Research on maturation rates of boys and girls indicated that girls, age six to eight, were more mature than boys of the same age, psychologically, physiologically, and by inference, intellectually.[15] Girls generally excelled in manual dexterity and rapid perception of details.[16] Female superiority in verbal functions was noted from infancy to adulthood.[17] While boys generally outscored girls on performance tests of intelligence, no difference in arithmetic reasoning was seen in first grade children.[18] In school achievement girls were superior to boys in subjects depending largely on verbal abilities, memory, and perceptual accuracy.[19]

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[15]Anne Anastasi, Differential Psychology (New York: The MacMillan Company, 1961), pp. 452-466.

[16]Ibid., p. 471. [17]Ibid., p. 472

[18]Ibid., p. 476. [19]Ibid., p. 493.

On the basis of the literature in the area of differential psychology, there appeared to be a close relationship between the areas of intellectual and academic superiority of girls and the tasks of conservation of quantity. It was, therefore, hypothesized that girls would score higher on a test of conservation of quantity than boys. The methods used for compiling scores of individual boys and girls and the model used for analyzing the scores were identical to the methods used in hypothesis one.

In stating hypothesis three, it was expected that there would be a difference in the proportion of boys and girls who conserved after having studied science by means of the methods and materials of the two different science programs. The testing of this hypothesis represented an attempt to study possible interactions between treatments and sex.

Although interaction effects were analyzed by means of the analysis of covariance model used in hypotheses one and two, it was decided by the writer that for hypothesis three, an analysis model would be used that allowed for the incorporation of the data collected on all of the pupils. The present model analyzed differences in proportions of boys and girls who conserved under the two treatment conditions. Because of the make-up of the model, all children were classified in a dichotomous fashion as conservers or non-conservers. In this way the proportion of conservers to non-conservers was determined for each of the sub-groups in the study. A child who circled the conservation response on each of tasks one, two, and four was designated as a conserver. The circling of any other response resulted in the child being designated a non-conserver.

The model used for testing hypothesis three was Goodman's[20] large sample multiple comparison technique as described by Marascuilo.[21]

In hypothesis four it was predicted that more children who studied science under SCIS methods and materials would conserve weight than children who had the usual science program. Conservation of weight data was treated as being of a dichotomous nature. That is, if a child circled the white box in task three, he was scored as "conserving." If he circled any of the other three boxes, he was scored as "non-conserving." Because of the nominal nature of the data thus collected, it was decided that a chi square technique was the appropriate model for analysis purposes.

In stating hypothesis five it was expected that more children who studied science under SCIS methods and materials

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[20]Goodman's large sample multiple comparison technique

$$\sum \frac{(\hat{\Delta}_j - \hat{\Delta}_o)^2}{\text{var}\ (\hat{\Delta}_j)}, \quad \text{where} \quad \hat{\Delta}_j = \hat{p}_{t_j} - \hat{p}_{nt_j}$$

The null hypothesis tested by this statistic is: There is no difference in the proportion who conserve under treatment and no treatment conditions for group a or b.

[21]Leonard A. Marascuilo, "Large Sample Multiple Comparisons," Psychological Bulletin, 65:280-290, 1966.

would conserve liquid quantity than children who had the usual science program. Data were collected and analyzed in a manner identical to that used in the conservation of weight task.

In hypothesis six it was predicted that more children who studied science under SCIS methods and materials would conserve continuous solid quantity than children who had the usual science program. Again, data were collected and analyzed in a manner identical to that used in the conservation of weight task.

In hypothesis seven it was expected that more children who studied science under SCIS methods and materials would conserve discontinuous solid quantity than children who had the usual science program. These data, too, were collected and analyzed in an identical manner to that used in the conservation of weight task.

For the purpose of analyzing the data related to each of the research hypotheses discussed, the following null hypotheses were tested:

1. There are no differences between children exposed to the methods and materials of the SCIS science program and the methods and materials of the usual science program on a test designed to measure conservation of quantity.

   $(H_{0_1}: CQ_E = CQ_C)$

2. There are no differences between boys and girls on a test designed to measure conservation of quantity. (H_{O_2}: $CQ_M = CQ_F$)
3. There are no differences in the proportion of boys and girls who conserve after having studied science by means of the methods and materials of the SCIS program or after having studied science by means of the usual program. (H_{O_3}: $P_{T_M} - P_{T_F} = P_{NT_M} - P_{NT_F}$)
4. On a test of conservation of weight, there are no differences between students who studied science in accordance with the methods and materials set by SCIS and students who received the usual science program. (H_{O_4}: $CW_E = CW_C$)
5. On a test of conservation of liquid quantity there are no differences between students who studied science in accordance with methods and materials set by SCIS and students who received the usual science program. (H_{O_5}: $CLQ_E = CLQ_C$)
6. On a test of conservation of continuous solid quantity, there are no differences between students who studied science in accordance with methods and materials set by SCIS and students who received the usual science program. (H_{O_6}: $CCSQ_E = CCSQ_C$)

7. On a test of conservation of discontinuous solid quantity, there are no differences between students who studied science in accordance with the methods and materials set by SCIS and students who received the usual science program. (H_{O_7}: $CDSQ_E = CDSQ_C$)

A summary of all of the hypotheses, scoring interpretations, and models used for analyzing data is found in Table 6.

Summary.--In this chapter the background and the general design of the study were outlined. Methods and materials used with the experimental and control groups were described. Evaluative materials were described and methods of collecting data were explained. Finally, a review of each hypothesis and the models that were used to test them were discussed.

TABLE 6.--Summary of hypotheses and models used to analyze data.

Statement of Hypotheses	Filmed Tasks Involved	Scoring Interpretation	Model Used for Analyzing Data
H_1: Children who studied science by means of SCIS methods and materials will score higher on a test of conservation of quantity than children who had the usual science program.	1--Conservation of liquid quantity 2--Conservation of continuous solid quantity 4--Conservation of discontinuous solid quantity	Two points per conservation response circled. One point per transition response circled. Zero points per non-conservation response circled.	Analysis of covariance $\alpha = .02$
H_2: Girls will score higher than boys on a test of conservation of quantity.	Same as H_1	Same as H_1	Same as H_1
H_3: There is a difference in the proportion of boys and girls who conserve after having studied science by means of SCIS methods and materials versus having studied science by means of the usual science program.	Same as H_1	A child who circles the conservation response for all three tasks is designated a <u>conserver</u>. All other children are designated <u>non-conservers</u>.	Goodman's large sample multiple comparison technique $\alpha = .02$
H_4: More children who studied science by means of SCIS methods and materials would conserve weight than children who had the usual science program.	3--Conservation of weight	A child who circles the white box for task three on the answer sheet is designated a <u>conserver</u>. All other children are designated non-conservers.	Chi-Square technique $\alpha = .02$
H_5: More children who studied science by means of SCIS methods and materials would conserve liquid quantity than children who had the usual science program	1--Conservation of liquid quantity	Same as H_4	Same as H_4
H_6: More children who studied science by means of SCIS methods and materials would conserve continuous solid quantity than children who had the usual science program.	2--Conservation of continuous solid quantity	Same as H_4	Same as H_4
H_7: More children who studied science by means of SCIS methods and materials would conserve discontinuous solid quantity than children who had the usual science program.	4--Conservation of discontinuous solid quantity	Same as H_4	Same as H_4

CHAPTER IV

RESULTS AND EVALUATION

This chapter consists of a restatement of the seven null hypotheses that were tested in this study, a presentation of data collected, and a summary of findings. Each hypothesis is discussed individually. Pertinent data are presented in tables throughout the chapter. Additional data are found in the Appendix.

Collection and Compilation of Data.--Data were collected for this study by administering a four question test consisting of four film clips designed to measure each child's ability to conserve liquid quantity, continuous solid quantity, discontinuous solid quantity, and weight. Each child marked his responses on a color-coded answer form. On the basis of his answer, a child was scored as being: (1) able to conserve, (2) unable to conserve, or (3) in transition for each individual task.

Results on the tasks involving conservation of liquid quantity, conservation of continuous solid quantity, and conservation of discontinuous solid quantity were combined for the purpose of determining overall achievement of conservation of quantity. To do this, numerical values were assigned to the answers for the three tasks. Two points were awarded for each conservation response, one point for each transition response, and zero points for each non-conservation response given by the child. A child who scored six points on the three conservation of quantity tasks was judged as having achieved the developmental stage called concrete operations. A child who scored zero points was judged as pre-operational in his thinking. A child who scored one to five points was judged to be in various degrees of transition between the pre-operational stage and the concrete operational stage.

Hypotheses Tested.--Seven hypotheses that related conservation ability to specified science experiences were tested in this study. These were:

1. There are no differences between children exposed to the methods and materials of the SCIS science program and the methods and materials of the usual science program on a test designed to measure conservation of quantity. (H_{O_1}: $CQ_E = CQ_C$)
2. There are no differences between boys and girls on a test designed to measure conservation of quantity. (H_{O_2}: $CQ_M = CQ_F$)

3. There are no differences in the proportion of boys and girls who conserve after having studied science by means of the methods and materials of the SCIS program or after having studied science by means of the usual program. (H_{0_3}: $P_{T_M} - P_{T_F} = P_{NT_M} - P_{NT_F}$)

4. On a test of conservation of weight, there are no differences between students who studied science in accordance with the methods and materials set by SCIS and students who received the usual science program. (H_{0_4}: $CW_E = CW_C$)

5. On a test of conservation of liquid quantity there are no differences between students who studied science in accordance with methods and materials set by SCIS and students who received the usual science program. (H_{0_5}: $CLQ_E = CLQ_C$)

6. On a test of conservation of continuous solid quantity, there are no differences between students who studied science in accordance with the methods and materials set by SCIS and students who received the usual science program. (H_{0_6}: $CCSQ_E = CCSQ_C$)

7. On a test of conservation of discontinuous solid quantity, there are no differences between the students who studied science in

accordance with the methods and materials set by SCIS and students who received the usual science program. (H_{O_7}: $CDSQ_E = CDSQ_C$)

Changes in Student Population.--When this study began in January, 1968, there were eighty-seven children in the four classes involved in the study. Forty-seven of the children were boys and forty were girls.

TABLE 7.--Number of pupils at the start of the study.

Group	Boys	Girls	Total
A	12	10	22
B	12	10	22
C	12	10	22
D	11	10	21
	47	40	87

During the course of the study six children moved from the school or the school district. One girl was absent from all post-test sessions and make-up sessions. Consequently a net loss of seven students resulted during the course of the study.

TABLE 8.--Number of pupils at the completion of the study.

Group	Boys	Girls	Total	Losses
A	11	9	20	2
B	11	10	21	1
C	11	9	20	2
D	10	9	19	2
	43	37	80	7

Pre-Test Data.--All of the first grade and first-second grade (transition) pupils in the Cornell School, Okemos, Michigan, were randomly assigned by sex to an experimental or a control group for the purpose of studying science. Children in the experimental group studied science by means of the methods and materials of the SCIS elementary science program. Children in the control group studied science by means of the school's usual program.

All children were given a pre-test to determine their ability to conserve quantity and to determine whether, in spite of the random assignment procedure carried out by the investigator, any initial differences existed among the groups. It was found that there were no significant differences among the mean scores of the experimental group boys, experimental group girls, control group boys, and control group girls on the pre-test (F=1.05, df 3.77). Pre-test data are given in Table 9.

TABLE 9.--Mean scores of the experimental and control groups on the pre-test of conservation of quantity.

	Experimental Group		Control Group	
	Boys	Girls	Boys	Girls
Number of Children[a]	22	19	21	18
Mean Score	3.14	2.58	2.86	1.91
Standard Deviation	2.30	2.30	2.36	2.22
Group Mean	2.90		2.26	
Group Standard Deviation	2.40		2.30	

[a]The number of children was adjusted so that only the scores of children who took the post-test are reflected in these data.

<u>Conservation of Quantity Data.</u>--It was hypothesized that children exposed to the methods and materials of the SCIS science program would score higher on the three conservation of quantity tasks than children who received the usual science program. Data related to this hypothesis are given in Tables 10 and 11.

TABLE 10.--Mean scores of the experimental and control groups on the post-test of conservation of quantity.

	Experimental Group		Control Group	
	Boys	Girls	Boys	Girls
Number of Children	22	19	21	18
Mean Score	4.73	4.58	4.38	3.56
Standard deviation	2.24	1.95	2.21	2.38
Group Mean	4.66		3.90	
Group Standard Deviation	2.11		2.27	

These data were analyzed by means of an analysis of covariance model with a pre-established rejection level set at .02. The results of this analysis indicated that there were no significant differences between the group of children who studied science by means of SCIS methods and materials and the group of children who had the usual science program. The results also indicated no interaction between treatment and sex.

TABLE 11.--Analysis of covariance data pre-test, post-test, and adjusted results analyzing the scores of seventy-two children on the test of conservation of quantity.

Source of Variance	df	Sums of Products			Adjusted Sum of Squares			
		Pre-test	Cross-Products	Post-Test	df	SS	MS	F^a
Treatment	1	12.64	14.16	16.05				
Sex	1	20.19	15.83	12.50				
Interaction	1	0.36	0.16	0.55				
Error	68	370.44	214.67	281.33	67	156.93	2.34	--
Treatments and Error	69	383.07	428.83	297.38				
Adjusted Treatment Effects					1	4.36	4.36	1.86 NS
Sex and Error	69	390.63	230.50	293.83				
Adjusted Sex Effects					1	0.78	0.78	0.33 NS
Interaction and Error	69	370.80	214.82	281.38				
Adjusted Interaction					1	0	0	0

[a] $\alpha = .02$

Differential Acquisition of Conservation of Quantity by Boys and Girls.--As reported earlier, review of the literature related to differential psychology[1] and discussions with teachers of primary grade children had led the investigator to expect girls to score higher on a test of conservation of quantity than boys. The raw data served as ample evidence that girls did not score higher than boys on the conservation tasks used in the study. In both the experimental and the control groups the mean scores of the boys exceeded the mean scores of the girls on the post-test (see Table 10). The results of the analysis of covariance indicated no significant differences between the mean score of the boys and the mean score of the girls. Table 11 contains a summary of pertinent data and tests related to this hypothesis. The procedures used in carrying out the analysis of covariance are given in the Appendix.

Interaction between Treatments and Sexes.--It was recognized by the investigator that the analysis of covariance model used to test null hypotheses one and two was equally useful in testing possible interactions between treatments and sexes. However, it was the desire of the investigator to determine whether there was a

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[1]Anastasi, op. cit., pp. 452-466.

difference between boys and girls in the proportion of conservers and non-conservers under each treatment condition. In this way the data on all of the boys and girls were used for testing purposes. The Goodman's large sample multiple comparison technique as described by Marascuilo[2] was used. By using this model, proportions of boys in both the treatment and the control groups who conserved were compared simultaneously to proportions of girls in the two groups who conserved.

Because of the "either/or" nature of the Goodman model, data were treated in a binary fashion. A child who indicated conservation responses on the three conservation of quantity tasks was designated a "conserver." A child who gave any other response was designated a "non-conserver." In the group of children who studied science by means of SCIS methods and materials, sixteen out of twenty-two boys and eleven out of nineteen girls were conservers. In the group of children who had the usual science program, thirteen out of twenty-one boys and six out of eighteen girls were conservers. Inspection of Tables 12 and 13 indicates no significant interactions between boys, girls, and treatments in the study.

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[2]Marascuilo, op. cit., pp. 280-290.

TABLE 12.--Number of the boys and girls who were able to conserve quantity under the treatment and non-treatment conditions.

	Boys		Girls		Totals
	T	NT	T	NT	
Conservers	16	13	11	6	46
Non-conservers	6	8	8	12	34
Total	22	21	19	18	80

TABLE 13.--Analysis of data on the interaction between treatment and sex on a test of conservation of quantity using Goodman's large sample multiple comparison technique, N = 80.

	Proportion of Conservers, Treatment Group	Proportion of Conservers, Control Group	Chi Square
Boys	16:22	11:19	0.50^{a} NS
Girls	13:21	6:18	

[a] $\alpha = .02$.

Conservation of Weight.--Children in the experimental group were given a series of lessons designed to develop an understanding of atomism and reversibility. Thus, children who had acquired an understanding of the concept of atomism were expected to recognize that substances were made up of atoms and that rearrangement of the atoms did not affect the weight of those substances. In a similar way, children who had had experiences with the concept of reversibility were expected to know that physical rearrangement of substances were negated by additional rearrangements that returned the substances to their original forms. Thus, rearrangement of shapes did not necessarily result in changes of weight.

On the basis of these experiences it was hypothesized that more children who had studied science by means of SCIS methods and materials would conserve weight than children who had had the usual science program. Data were collected on a child's response to a filmed Piagetian-like conservation of weight task. If the child gave a conservation response he was considered a conserver. Any other response was considered a non-conservation answer and the child classified as a non-conserver. It should be noted that for the purpose of reporting results of the conservation of liquid quantity, conservation of continuous solid quantity, and conservation of discontinuous solid quantity tasks all data were collected and analyzed by means of the statistical techniques used for the conservation of weight task.

It was found that, of the children in the SCIS group, twenty-nine out of forty-one conserved. In the control group twenty-six out of thirty-nine conserved. In both the experimental and control groups a total of 68.75 per cent of the children were able to conserve weight. There were no significant differences in ability to conserve weight between the two groups. Results of the analysis of these data are found in Table 14.

TABLE 14.--Chi square analysis of the forty-three boys and thirty-seven girls on the conservation of weight task.

	Conservers	Non-Conservers	Chi-Square[b]
Experimental	29	12	0.14[a] NS
Control	26	13	
Totals	55	25	

[a] α level = .02 [b] df = 1

Conservation of Liquid Quantity.--Children who studied science by means of SCIS methods and materials were given a series of five lessons designed to acquaint them with the concept of serial ordering. Six lessons were presented that dealt with multiple relationality, the concept that "tall and thin" can be equal in mass to "short and fat." These children also had three lessons that dealt with the concept of reversibility. As a result of having these experiences the investigator hypothesized that more children who had studied science by means of the methods and materials of the SCIS program would conserve liquid quantity than children who had studied science by means of the usual program. On the basis of the data collected and analyzed by the Chi Square model there were no significant differences between the experimental and the control groups. Thirty-one out of forty-two children in the experimental group conserved liquid quantity and twenty-four out of thirty-nine children in the control group conserved on this task. A total of 68.75 per cent of the children in both groups were conservers. These results are found in Table 15.

TABLE 15.--Chi square analysis of the eighty children on the conservation of liquid quantity task.

	Conservers	Non-Conservers	Chi-Square[b]
Experimental	31	10	1.75[a] NS
Control	24	15	
Totals	55	25	

[a] α level = .02 [b] df = 1

<u>Conservation of Continuous Solid Quantity</u>.--Children who had studied science by means of SCIS methods and materials were given a series of seven lessons designed to provide experiences in observing continuous solid objects such as wood and metal. Four lessons were designed to allow a child to compare solid objects on the basis of such properties as size and shape and to order the objects by one or more dimensions. As a result of these experiences the children in the SCIS group were provided with opportunities to practice the mental operations of

multiple classification, serial ordering, and multiple relationality--all deemed useful in achieving concrete operations and with it, the ability to conserve continuous solid quantity. Therefore, it was hypothesized that more children who studied science by means of the methods and materials in the SCIS program would conserve continuous solid quantity than children who studied science by means of the usual program. Data were compiled in the manner described for the conservation of weight task. These data were analyzed by means of a chi square model. It was found that there were no significant differences between the experimental and control groups. Twenty-eight out of forty-one children in the experimental group and twenty-three out of thirty-nine in the control group conserved. A total of 63.75 per cent of the children in the experimental and control groups were conservers. Results of the analysis of these data are found in Table 16.

TABLE 16.--Chi square analysis of the eighty children on the conservation of continuous solid quantity task.

	Conservers	Non-Conservers	Chi Square[b]
Experimental	28	13	
Control	23	16	0.74[a] NS
Totals	51	29	

[a] α level = .02　　[b] df = 1

Conservation of Discontinuous Solid Quantity.--The SCIS unit Material Objects was comprised of four lessons that were particularily useful in developing an understanding of spatial arrangement and rearrangement of discontinuous solid quantities. These were the activities involving the observation, sorting, and ordering of rocks and the activity in which rock-candy was transformed into lump sugar. These activities were believed by the investigator to be particularily useful in developing the mental operations of multiple classification.

As a result of these experiences this investigator hypothesized that more children who studied science by means of the methods and materials in the SCIS program would conserve discontinuous solid quantity than children who studied science by means of the usual program. Data were compiled in a manner identical with that used in the preceding three tasks. Using a chi square model to analyze the data, no significant differences between experimental and control groups were observed. Thirty-four out of forty-one children in the experimental group and twenty-eight out of thirty-nine children in the control group conserved on this task. This means that 77.5 per cent of the children in both the experimental and control groups conserved on this task. Results of the analysis of these data are found in Table 17.

TABLE 17.--Chi square analysis of the eighty children on the conservation of discontinuous solid quantity task.

	Conservers	Non-Conservers	Chi Square[b]
Experimental	34	7	1.39^a NS
Control	28	11	
Totals	62	18	

[a] α level = .02 [b] df = 1

Other Findings.--The investigator was concerned with determining differences in the rate of acquisition of the four conservation tasks. The proportions of children who conserved on the four conservation tasks were compared by using a chi square model and testing the null hypothesis that equal numbers of children conserved on each of the four tasks. The results of the analysis of these data indicated that the null hypothesis could not be rejected at the two per cent level of significance. Thus, no differences in acquisition of the four conservation tasks were seen in the children used in this study. The analysis of these data are included in Table 18.

The investigator also attempted to measure differences in conservation of quantity ability from pre-test to post-test within the four sub-groups of children in this study. Consequently, using a t-test for correlated means, the pre-test mean and the post-test mean of the

TABLE 18.--Chi square analysis of the number of conservers and non-conservers on the four conservation tasks.

	Weight	Liquid	Cont. Solid	Discont. Solid	Totals
Conserve	55	55	51	62	223
Non-conserve	25	25	29	18	97
Totals	80	80	80	80	320
Chi Square[a]	3.76 NS[b]				

[a] α level = .02 [b] df = 3

experimental group boys were compared for significant differences. In an similar manner the pre-test and post-test means of the conservation of quantity tasks for experimental group girls, control group boys, and control group girls were compared. There were no significant differences between pre-test and post-test means on the conservation of quantity test for experimental group boys, control group boys, or control group girls. There were significant differences beyond the .01 level between the pre-test and post-test means of the experimental group girls. The results of these analyses are found in Table 19.

Summary.--The first part of this chapter presented the data collected in this study. Each major hypothesis was restated, the data related to that hypothesis reported, and a statement of acceptance or rejection of each

TABLE 19.--t-test for determining significance between pre-test and post-test means of experimental group boys, experimental group girls, control group boys, and control group girls on the test of conservation of quantity, N = 80.

	Experimental		Control	
	Boys	Girls	Boys	Girls
Pre-test mean	3.14	2.58	2.86	1.91
Post-test mean	4.73	4.58	4.38	3.56
Difference	1.59	2.00	1.52	1.65
t[a]	1.939 NS	2.740[b]	1.949 NS	2.065 NS

[a]Significance level: .02 p = 2.44; .01 p = 2.72.

[b]Significant beyond .01.

hypothesis given. It was seen that the only significant differences found were the differences between pre-test and post-test mean scores among the experimental group girls on the test of conservation of quantity. All other findings failed to reach the necessary level of significance established for this study. Table 20 contains a summary of the hypotheses tested in this study, model used for testing each hypothesis, and the results.

TABLE 20.--Summary of the analyses of data for each of the major hypotheses tested.

Hypothesis	Model Used	Results
1. Conservation of quantity, experimental versus control group.	Analysis of covariance	No significant differences
2. Conservation of quantity, boys versus girls	Analysis of covariance	No significant differences
3. Interaction of treatments and sexes	Goodman's large sample multiple comparison technique	No significant differences
4. Differential attainment of conservation of weight	Chi square	No significant differences
5. Differential attainment of conservation of liquid quantity	Chi square	No significant differences
6. Differential attainment of conservation of continuous solid quantity	Chi square	No significant differences
7. Differential attainment of conservation of discontinuous solid quantity	Chi square	No significant differences

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

A summary of the study is presented in this chapter together with the main findings and conclusions. Implications of the findings and recommendations for further investigations are also given in the chapter.

Pupils and Procedures.--First grade children in the Cornell School, Okemos, Michigan, were randomly assigned to two groups for the purpose of science instruction. One group of forty-one children, the experimental group, studied science by means of the methods and materials of the SCIS program. The other group of thirty-nine children, the control group, studied science by means of the usual science program. The study ran for eighteen weeks. All children were pre-tested and post-tested for the abilities to conserve quantity and weight. For the purpose of determining a child's ability to conserve, four Piagetian-like conservation tasks were filmed and presented to the children. The answers the children gave to these four tasks constituted the data for determining conservation abilities.

Findings.--Seven hypotheses relating science experiences and conservation ability were tested in the study.

The following are the results of testing the null hypotheses:

1. There were no significant differences between children who had the SCIS program and children who had the usual science program in the ability to conserve quantity.
2. There were no significant differences between boys and girls in the ability to conserve quantity.
3. There were no significant interactions between boys and girls and treatments with regard to the ability to conserve quantity.
4. There were no significant differences between the number of children who conserved weight in the experimental and control groups.
5. There were no significant differences between the number of children who conserved liquid quantity in the experimental and the control groups.
6. There were no significant differences between the number of children who conserved continuous solid quantity in the experimental and control groups.
7. There were no significant differences between the number of children who conserved discontinuous solid quantity in the experimental and control groups.

In addition to the results of the analysis of the data pertaining to the major hypotheses in the study, the following results were obtained by the investigator:

1. The mean score of girls in the experimental group was significantly higher (beyond .01) on the post-test of conservation of quantity than it was on the pre-test. The mean scores on the pre-test and post-test were not significantly different for experimental group boys, control group boys, or control group girls.
2. There was no significant difference in the number of children who were able to conserve on any of the four conservation tasks used in this study.

Discussion of Results.--As a result of testing the hypotheses of this study, the following statments appear justified:

1. There were no differences in attainment of concrete operations between children who had the SCIS science program and children who had the school's usual program.
2. There were no significant differences in attainment of concrete operations by boys or girls.
3. There appeared to be no significant temporal differences between a child's acquisition of conservation of quantity and his acquisition of conservation of weight.

Statistically, there were no differences between children in the experimental and the control group on the conservation of quantity test. However, both the experimental and the control groups were, in reality, made up of sub-groups of boys and girls. In attempting to measure main treatment effects, large changes in one sub-group were easily diluted by small changes in the other sub-group. This appears to be the case in the experimental group where a large gain in mean score from pre-test to post-test among the girls lost its significance when girls' and boys' scores were pooled for the purpose of analyzing main treatment effects. By using a correlated t-test on the mean scores of the four individual sub-groups it was found that a significant gain had been made by the experimental group girls. No other sub-group showed a significant gain in mean score. This gain by the experimental group girls was believed, by the investigator, to be indicative of accelerated growth.

The investigator recognized the fact that the treatment period of eighteen weeks may not have been long enough to produce significant changes in the developmental growth of the children in the study. More time may have been needed to provide the depth and the breadth of experiences necessary for providing a child with the perceptual insights and intellectual skills necessary for accelerating intellectual development. On the other hand, too long a treatment could create an equally difficult problem for an investigator. Over a long period of time growth resulting from experiences may be masked by growth due to neural maturation.

Another factor that may have affected the results in the study was the small number of tasks used to determine and quantify the presence of conservation in each child. The statistical treatments applicable to the study were highly sensitive to the small range of scores. Had ten tasks rather than four been used for the purpose of testing conservation ability, a scoring range of zero to twenty would have resulted. Instead, the scores ranged from zero to six and changes in mean scores were, therefore, limited.

The basic question asked in the study was, can certain science experiences influence developmental growth as measured by selected Piagetian conservation tasks? On the basis of the data collected and the discussion related to this data, the answer is no. However, this is not an unequivocal no in light of the findings regarding the gain scores of the experimental group girls and the apparent need for a more sensitive testing instrument.

A second finding in the study suggests that there were no differences between boys and girls in conservation ability. On the basis of writings by Anastasi[1] on differential psychology, personal discussions with teachers of young children, and somewhat more recently, on an unpublished report by Sigel and Mermelstein,[2] it was

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[1]Anastasi, <u>op. cit.,</u> pp. 452-466.

[2]Irving Sigel and Egon Mermelstein, "Effects of Non-Schooling on Piagetian Tasks of Conservation" (paper presented at the A.P.A. meeting, September, 1965).

expected that girls would out-perform boys on the conservation of quantity tasks used in this study. A superiority of girls over boys in the ability to conserve quantity was not borne out in any way. It is the opinion of the investigator that the expectation of superior performance on conservation tasks by girls was related to the increased verbal competencies of girls over boys.[3] Because of female superiority in verbal functions, a general feeling exists that females are superior in all intellectual functions. In the case of conservation, as used in this study, verbal ability was not involved. As a result the expected superiority of girls over boys was not apparent.

The third finding in the study was related to differential acquisition of conservation of weight and conservation of quantity. In the study statistical analysis of differences in the numbers of children who conserved weight and quantity indicated that there were no differences in the number of first grade children who conserved on the two tasks. On a percentage basis the per cent of children who conserved weight was almost identical to the per cent who conserved quantity. This finding disagrees somewhat with Piaget's theoretical position. Piaget,[4]

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[3]Anastasi, loc. cit.

[4]Piaget, op. cit.

Lovell and Ogilvie,[5] and Elkind[6] found a sizeable delay between a child's acquisition of conservation of quantity and his acquisition of conservation of weight. According to the findings of Piaget and his co-workers, seven to eight year old children were able to conserve quantity, but a time lag of one to two years ensued before a child was able to conserve weight. The findings of McRoy,[7] on the other hand, agreed closely with the findings in this study--that is, that there was no discernable temporal difference in acquisition of conservation of quantity over conservation of weight. An explanation for this last finding may be found in the filmed presentation of stimuli for the conservation of weight task. Children were shown two balls of pla-dough. They saw both balls placed on a scale and were able to see that the same weight was registered by both balls. They thus had both audio and visual reinforcement of the fact that the two pla-dough balls were of the same weight. It was notable that in the classic Piagetian presentation as carried out by Smedslund[8] and Lovell and Ogilvie,[9] a balance rather than a scale was used. In the experiments

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[5]Lovell and Ogilvie, op. cit.

[6]Elkind, op. cit. [7]McRoy, op. cit.

[8]Smedslund, "The Acquisition of Conservation of Substance and Weight in Children II," loc. cit.

[9]Lovell and Ogilvie, loc. cit.

performed by these investigators, children were given some training experience with the balance. The operation of the balances was dismissed as "a very easy problem for all the children."[10] It was possible that the use of a balance was not the easy problem it was believed to be. On the other hand, in the filmed presentation of stimuli used in this study, the pointer on the scale moved to the same point on the scale as each of the two balls were placed on the scale's pan. This may have provided a child with more meaningful information about the equal weight of the two balls at the outset. A second explanation for the results on conservation of weight may be found in Gruen's[11] work on the affect of questions asked of children and their earlier acquisition of the conservation trait. Children who were asked only to affirm or negate conservation on a task were found to indicate earlier achievement of this trait than children who were asked to explain their reasons for giving conservation or non-conservation responses. Thus, the type of response called for in this task may account for the apparent "early" acquisition of conservation of weight by almost seventy per cent of the children in this study.

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[10] Smedslund, op. cit., p. 72.

[11] Gerald Gruen, "Note on Conservation: Methodological and Definitional Consideration," Logical Thinking in Children, edited by Irving Sigel and Frank Hooper (New York: Holt, Rinehart and Winston, 1968), pp. 495-499.

General Conclusions.--Piaget, in taking a position on the importance of experience for implementing or accelerating a child's developmental growth, stated that experience was but one of four crucial factors.[12] He believed that experience alone was insufficient to promote the transition from pre-operations to concrete operations. Piaget believed that neural maturation, social transmission, and equilibration were also needed by the child for this growth to take place.

The present study was designed primarily to investigate the growth that took place in a group of first grade children who had science experiences deemed useful in promoting or accelerating developmental growth. These children were compared with another group of first grade children who did not have the requisite science experiences.

The results of this study indicated that there were no differences in developmental growth between children who had the SCIS science program and children who had the usual science program. In addition, there were no differences between boys and girls in the attainment of concrete operations. However, the girls in the SCIS program scored significantly higher on the post-test than on the pre-test of conservation of quantity. This was construed as indicative of accelerated growth for this group.

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[12] Piaget, loc. cit.

No conclusive evidence was produced to indicate the value of science experiences in promoting developmental growth. This tended to add support to Piaget's position that experiences alone were insufficient to accelerate a child's rate of acquisition of concrete operations.

Implications for Science Educators.--On the basis of the findings reported in this study it appeared that developmental growth may be useful as both a goal and a measure of the success of an early elementary science program. In order for developmental growth to be a meaningful goal and a true measure of the success of a science program more research into what to teach and how to evaluate outcomes is needed.

This study dealt only with tasks related to the development of concrete operations as revealed by a child's ability to conserve quantity and weight. Other conservation tasks as well as other aspects of Piaget's work in the child's development of logic, time-concepts, chance, and reasoning may lend themselves to inclusion in science programs designed for young children. It appears that many of the tasks developed by Piaget as descriptions or measures of child development may serve equally well as a core about which new science programs are built.

Additional Implications.--As a result of the data collected in this study some questions regarding the order of acquisition of conservation of weight were raised in this investigator's mind. As mentioned earlier, Piaget believes that acquisition of conservation of weight by young children follows acquisition of conservation of quantity by approximately two years. This period of delay was not seen in this study. There were no differences in the ability to conserve either weight or quantity among the eighty children in this investigation. These findings agree closely with those of McRoy[13] which were reported in 1967. They disagree with the findings of the major American replication of Piaget's work done by Elkind[14] in 1961. The seven year time lapse since 1961 may be a crucial one. The impact of advanced mass media, particularly color television, and the development of sophisticated games and toys have provided young children with experiences and social transmission unknown to children, even seven years ago. In addition, advanced medical developments during the past seven years such as vaccines that protect children from measles, mumps, cold and flu viruses have enabled these children to grow up at a more rapid rate and with fewer debilitating illnesses. Under such conditions it is possible that faster and better physical development has resulted in proportionately faster and better neurological development, too. Some further research in to the area of age at which developmental stages are reached seems appropriate at this time.

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[13]McRoy, loc. cit.

[14]Elkind, loc. cit.

Recommendations.--Analysis of data collected in this study indicated that the limitations discussed in the first chapter of this dissertation were real. The fact that the total number of children used was but eighty placed severe limitations on the possibility of finding significant differences among the various groups. The narrow geographical area from which the population was drawn placed a limitation on the generalizability of results. Therefore, a replication of this work with larger and more diverse numbers of children would appear to provide a fruitful area for investigation. A study in which more filmed tasks were used might also be of value. Only four films were used to measure developmental growth in this study. Four to six more films, carefully prepared to measure additional facets of the conservation concept would provide more data on each child and a more carefully defined hierarchy of development of the children in such a study.

Further investigation using techniques similar to those used in this study but done with children who were six months younger could provide more information about the success of a new science program in accelerating developmental growth. A large number of children in both the experimental and control groups in this study appeared to have reached the age at which transition to or attainment of the concrete operational stage was taking place regardless of the experiences being provided by the school. Fifty-five per cent of all the children indicated that they were able to conserve on all three quantity tasks on the post-test used in this study. Only twenty per cent of these same children were complete conservers on the pre-test. It is the opinion of the investigator that differences between experimental and control groups on a post-test would be clearer if the younger group of children were used.

The gains in mean score made by the experimental group girls was an important finding in the study. Additional work, in which an investigator concentrated on replicating and extending this phase of the present study would be of value to the educational community. By encompassing a larger number of girls and providing a wider variety of experiences, such a study could provide answers to questions of differential achievement by boys and girls as well as extending the work on the role of experiences in accelerating developmental growth.

The techniques employed in this investigation--namely using filmed sequences of Piagetian tasks, tape recorded audio in-put and color-coded answer sheets--appeared to be a useful and efficacious means of measuring the developmental growth of children. With modifications, augmentation, and standardization, the techniques and materials could prove to be the source of a useful, valid, and reliable instrument for measuring academic as well as developmental growth in first grade children. Additional work should be carried out in order to provide standardization data on these tasks.

A final recommendation involves using the materials developed in this study with individual children, as well as with groups of children. When the films and sound track are used with individual children, an experimenter is able to elicit a reason for a child's responses to the conservation inquiries. Based on the work of Gruen,[15] an investigator might expect somewhat different results from those obtained in this study. Therefore, a study in which groups of children are tested using both the techniques employed in this study and an oral feedback technique could provide additional information on the evaluative materials used in this study, as well as possible new insights into developmental growth.

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[15] Gruen, loc. cit.

APPENDIX A

SCRIPTS USED IN THE PRODUCTION OF THE FOUR FILM CLIPS

FILM CLIPS FOR USE AS EXPERIMENTAL STIMULUS MATERIAL

General Specifications: 16 mm, color, silent, 24 fps.

This film consists of four color shots of objects manipulated by an experimenter. The objects are arranged on a table with a vertical back board approximately 18" high. Both the table top and the back board are covered with a neutral background material. Lighting is arranged to effect three-dimensional modelling of the objects.

Each shot opens with a view of the initial arrangement of objects, which is held static while taped comments are played. Then the manipulation is accomplished by the experimenter, working from behind the table. Finally, the new arrangement is established for the viewer, and the film is stopped while more taped comments are played and the experimental subjects respond.

The shots are separated by leader. No titles of any kind are used.

Prepared by:

Robert O. Blunt
Film Production Unit
MSU-IMC

Action	Camera	Viewer
1. A transparent cylinder about 1½" in diameter and 14" high, stands with two beakers in the center of the table, with the cylinder on the left and the beakers at center and right of the group. The cylinder is empty. The beakers are partially filled, to a common level, each with a different colored liquid. Behind the beakers is a white card with a horizontal black line at the level of the liquid in the beakers. After 15 sec., ON CUE:	Camera axis level. Tight frame on beakers and the card behind them. Line on card appears to coincide with the liquid levels in the beakers. After 10 sec., camera rises, tilts down and zooms back to a moderately high angle view with about 1/3 frame clear above the vertical cylinder. When this view is established, cameraman cues experimenter for action.	Sees that the beakers contain equal amounts of liquid.
Experimenter's hand enters frame at top, picks up the right hand beaker and pours the liquid into the cylinder. Experimenter steps back.	Continue shot to cover action.	Sees all the liquid of one beaker transferred to the cylinder. Sees that the beaker is empty and that the liquid stands at a certain level in the cylinder.
Shot holds on static set after hand withdraws.	Continue shot for 20 sec. after action ends.	
2. Two small colored pies are seen side by side at the center of the table. One of these pies has been cut into 6 sectors. After 15 sec., ON CUE:	High angle with pies centered in frame. Shoot 15 sec., then cue experimenter for action.	Sees that the pies are of equal size and the same shape.

Action	Camera	Viewer
Experimenter's hand enters frame from the top, separates and spreads out the parts of the cut pie. Experimenter steps back.	Continue shot to cover action.	Sees that the parts spread out are all the parts of the cut pie.
Shot holds on static set after hand withdraws.	Continue shot for 20 sec. after action ends.	
3. A kitchen scale and two colored balls about 3" in diameter are seen in line at the center of the table, with the scale on the left.	Moderately high angle. Objects are tightly framed left-to-right, with about ¼ frame clear above the scale. Shoot 10 sec., then cue experimenter for action.	Sees that the colored balls are of equal size.
ON CUE: Experimenter's hand enters top of frame and places one ball on the scale. Experimenter steps back, then forward. His hand re-enters, removes first ball from the scale to the table, then places the second ball on the scale. Experimenter steps back, then forward. Hand re-enters and moves the second ball from the scale to the table. Experimenter steps back.	Continue shot to cover action.	Sees that the scale reading is the same for both balls, indicating that they are of equal weight. Sees the balls replaced on the table with no change after being weighed.
	Shot continues as camera zooms back to about ½ the initial focal length. The ball next to the scale is at frame center. Cameraman cues experimenter for next action.	Sees that there is no change in the objects as the image size decreases.

Action	Camera	Viewer
ON CUE: Experimenter's hands enter frame and roll the ball at frame center into a cylindrical shape. Experimenter steps back.	Shot continues for 20 sec. of action.	Sees one ball deformed, with no part of it being removed.
Shot holds on static set after hands withdraw.	Continue shot for 20 sec. after action ends.	
4. Two rectangular "buildings" are seen at the center of the table. They are set end-to-end, with the long aspect of the buildings facing the camera, and a space of about 3" between them. Each building consists of thirty-two 3/4" cube-shaped blocks, in two layers of 2 x 8 blocks each.	Moderately high angle. Buildings appear just below frame center. Shoot 15 sec., then cue experimeter for action.	Sees that the buildings are of equal size.
ON CUE: Experimenter's hand enters frame and rearranges the left-hand building into a stack of blocks consisting of 8 square layers of 4 blocks each. Experimenter steps back.	Continue shot to cover action.	Sees that all the blocks of the left-hand building are used to make the new stack, and that no other change occurs.
Shot holds on static set after hand withdraws.	Continue shot for 20 sec. after action ends.	

APPENDIX B

SCRIPTS USED TO TAPE AUDIO IN-PUT

Task 1

A. (Scene opens. Allow few seconds for observation.) "You see two glasses of colored water. The water has been colored to help you tell the glasses apart. Both glasses have EXACTLY the same amount of water in them."

B. (Water is poured. Allow a few seconds for observation.)

C. "NOW which container has more water in it: the glass with the green water, the container with the blue water or do they both have the same amount of water in them?

Open to part 1 of your answer sheet.

If you think that the GLASS with the GREEN WATER in the movie now has more water in it put a CIRCLE around the GREEN BOX near the number 1 on your answer sheet.

If you think that the CONTAINER with the BLUE WATER in the movie now has more water in it put a CIRCLE around the BLUE BOX near the number 1 on your answer sheet.

If you think that in the movie there is JUST AS MUCH green water in the glass as there is blue water in the container put a circle around the white box in part 1 of your answer sheet.

If you can not tell put a circle around the orange box in part 1 of your answer sheet."

Task 2

A. (Scene opens. Allow few seconds for observation.) "You see two pla-dough pies. They are colored to help you tell them apart. Both pies are EXACTLY the SAME SIZE."

B. (Red pie is fragmented. Allow time for observation.)

C. "NOW is there more blue pla-dough pie, is there more red pla-dough pie or is there just as much blue pie as there is red pie?

Open to part 2 of your answer sheet.

If you think there is now MORE blue pla-dough pie in the movie put a circle around the blue box near the number 2 on your answer sheet.

If you think there is now MORE red pla-dough pie in the movie put a circle around the red box near the number 2 on your answer sheet.

If you think there is now just as much blue pie as there is red pie in the movie put a circle around the white box in part 2 of your answer sheet.

If you can not tell, put a circle around the orange box in part 2 of your answer sheet."

Task 3

A. (Scene opens. Allow few seconds for observation.) "You now see two balls made of pla-dough. The balls have been colored to help you tell them apart. The yellow ball is exactly as heavy as the purple ball." (Each ball is placed on the scale.)

B. (Purple ball is rolled out. Allow time for observation.)

C. "NOW if each of these pla-dough shapes were put back on the scale would the yellow ball be heavier, would the purple sausage shape be heavier or would they both weigh the same?

Open to part 3 of your answer sheet.

If you think the yellow pla-dough ball in the movie is heavier put a circle around the yellow box near the number 3 on your answer sheet.

If you think the purple pla-dough sausage shape in the movie is heavier, put a circle around the purple box in part 3 of your answer sheet.

If you think that the yellow ball is just as heavy as the purple sausage shape in the movie put a circle around the white box on your answer sheet.

If you can not tell, put a circle around the orange box on your answer sheet."

Task 4

A. (Scene opens. Allow few seconds for observation.) "You see two buildings made of plastic blocks. The buildings are colored to help you tell them apart. Both buildings are made up of EXACTLY the same number of blocks."

B. (Blocks are rearranged. Allow few seconds for observation.)

C. "NOW which building has more blocks? The red building, the blue building or do they both have the same number of blocks?

Open to part 4 of your answer sheet.

If you think that the red building in the movie has more blocks, put a circle around the red box near the number 4 on your answer sheet.

If you think that the blue building in the movie has more blocks put a circle around the blue box in part 4 of your answer sheet.

If you think that the red building has just as many blocks as the blue building in the movie put a circle around the white box in part 4 of your answer sheet.

If you can not tell put a circle around the orange box in part 4 of your answer sheet."

APPENDIX C

ANSWER FORMS

Yellow	Red		Orange

1.

Blue	Green		Orange

2.

Blue-Green	Red		Orange

3. Yellow Purple Orange

4. Blue Red Orange

APPENDIX D

PROCEDURE FOLLOWED IN THE TRAINING SESSION FOR USING THE ANSWER FORM

TRAINING SESSION FOR USING THE ANSWER SHEET

For the purpose of obtaining data in this study, the children were shown four film clips of selected Piagetian-like conservation tasks. The children were asked questions about the films and were instructed to mark answers on a specially-prepared answer form.

In order to facilitate the proper use of this answer form, a five minute training session on how to mark answers was given to each group of children in this study. Children were brought from their classroom to a projection room and allowed to sit at any location where an answer sheet had been placed.

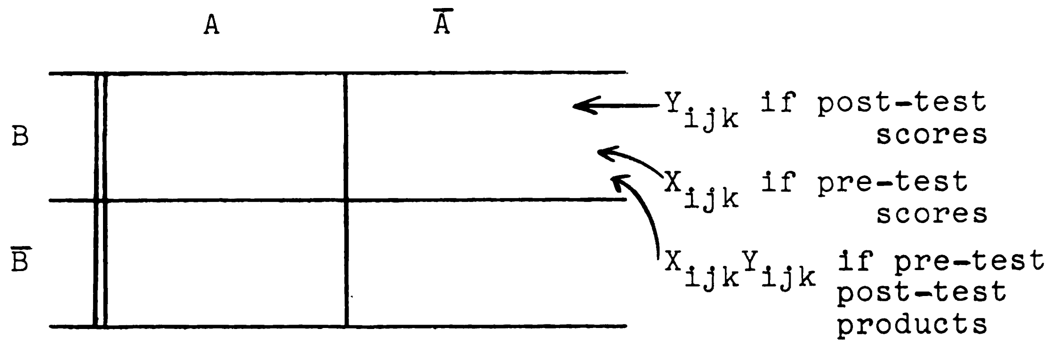
After all of the children has found seats, the investigator welcomed the children and told them that they were going to see some movies about which they would be asked some questions. Their attention was directed to the answer form on the desk in front of them. They were told that they would use this answer form for answering the questions about the movies. They were further told that they would be shown how to use the forms. They were asked to print their names on the cover of the answer form and then to open to the first page. They saw a single row of four one-half inch square boxes. The first box was colored yellow, the second box, red, the third box, white and the fourth box, orange. Two objects, one round and red and the other square and yellow were held up for each child to see. The child was then asked which object was round. They were told to circle the red box on the answer sheet if the red object was round; circle the yellow box if the yellow object was round; the white box if both objects were round; and the orange box if he could not tell which object was round. Each child's answer sheet was checked for correctness of choice and any questions that arose were answered.

APPENDIX E

ANALYSIS OF COVARIANCE
COMPUTATIONAL FORMULAS

The computational formulas used for the analysis of covariance in the study were compiled by Dr. Maryellen McSweeney of the Department of Counseling, Personnel Services, and Educational Psychology, Michigan State University. An example of one such analysis of covariance for determining the significance of differences between adjusted post-test mean scores follows. Data from the present study is used in the example given.

Pre-test scores are signified by X and post-test scores by Y. XX denotes a pre-test sum of squares, YY a post-test sum of squares, and XY a cross-product sum of squares. A refers to the main effect of treatment, B to the main effect of sex, AB to an interaction, E to error, and T to total.



A_{XX}, B_{XX}, AB_{XX}, and E_{XX} can be obtained from a pre-test ANOVA table.

A_{YY}, B_{YY}, AB_{YY}, and E_{YY} can be obtained from a post-test ANOVA table.

Boys

Experimental			Control		
X	Y	XY	X	Y	XY
5	6	30	2	1	2
0	6	0	6	6	36
3	6	18	0	2	0
6	6	36	4	6	24
4	6	24	2	4	8
4	6	24	0	6	36
6	6	36	0	0	0
2	6	12	6	6	36
6	6	36	2	6	12
6	6	36	6	2	12
3	6	18	0	6	0
6	6	36	0	3	0
5	6	30	6	6	36
0	0	0	4	6	24
6	6	36	6	6	36
0	0	0	1	2	2
4	6	24	5	6	30
2	6	12	6	6	36
ΣX 68	ΣY 96		56	80	
ΣX^2 340	ΣY^2 576	ΣXY 408	286	434	330

Girls

Experimental			Control		
X	Y	XY	X	Y	XY
3	6	18	0	4	0
0	6	0	0	4	0
6	6	36	0	6	0
3	1	3	6	6	36
0	3	0	4	6	24
1	2	2	0	3	0
2	6	12	4	6	24
6	6	36	4	4	16
0	0	0	5	5	25
2	6	12	1	4	4
4	4	16	0	0	0
6	6	36	2	0	0
4	4	16	2	6	12
5	6	30	0	0	0
2	6	12	0	0	0
6	6	36	0	0	0
0	6	0	6	6	36
2	2	4	0	4	0
ΣX 52	ΣY 82		34	64	
ΣX^2 236	ΣY^2 446	ΣXY 269	154	330	177

The following tables are used in making computations.

X - totals

	A	$\bar{A}$	
B	68	56	124
$\bar{B}$	52	34	86
	120	90	210

$$\sum_{j}\sum_{k}\sum_{i} X_{ijk}^2 = 1016$$

Y - totals

	A	$\bar{A}$	
B	96	80	176
$\bar{B}$	82	64	146
	178	144	322

$$\sum_{j}\sum_{k}\sum_{i} Y_{ijk}^2 = 1786$$

XY - totals

	A	$\bar{A}$	
B	408	330	738
$\bar{B}$	269	177	446
	677	507	1184

$$\sum_{j}\sum_{k}\sum_{i} XY = 1184$$

Compute the following quantities:

$$I = \sum_{jki}\sum\sum X_{ijk}\, Y_{ijk}$$ individual observations (72 pairs of values in sum)

$$II = \frac{\sum_{ik}\sum \left[\sum_{i} X_{ijk}\right]\left[\sum_{i} Y_{ijk}\right]}{18}$$ cell totals (4 pairs of values in sum)

$$III_C = \frac{\sum_{j} \left(\sum_{ki}\sum x_{ijk}\right)\left(\sum_{ki}\sum Y_{ijk}\right)}{36}$$ column totals (2 pairs of values in sum)

$$III_R = \frac{\sum_{k} \left(\sum_{ji}\sum x_{ijk}\right)\left(\sum_{ji}\sum Y_{ijk}\right)}{36}$$ row totals (2 pairs of values in sum)

$$IV = \frac{\left(\sum_{jki}\sum\sum X_{ijk}\right)\left(\sum\sum\sum Y_{ijk}\right)}{73}$$ grand totals

Then

Columns (Treatment)	$A_{XY} = III_C - IV$
Rows (Sex)	$B_{XY} = III_R - IV$
Interaction	$AB_{XY} = II - III_C - III_R + IV$
Error	$E_{XY} = I - II$

$$I = \sum_{j}\sum_{k}\sum_{i} X_{ijk} Y_{ijk} = 1184$$

$$II = \frac{(68)(96) + (56)(80) + (52)(82) + (34)(64)}{18}$$

$$III_C = \frac{(120)(178) + (90)(144)}{36}$$

$$III_R = \frac{(124)(176) + (86)(146)}{36}$$

$$IV = \frac{(210)(322)}{72}$$

Retain as many significant figures as possible during the intermediate stages of computation. Regression-associated procedures are extremely sensitive to rounding.

Compute the following quantities:

Error SS Adjusted for Regression

$$E'_{YY} = E_{YY} - \frac{(E_{XY})^2}{E_{XX}}$$

Column SS Adjusted for Regression

$$(A + E)'_{YY} = (A_{YY} + E_{YY}) - \frac{(A_{XY} + E_{XY})^2}{(A_{XX} + E_{XX})}$$

$$A'_{YY} = (A + E)'_{YY} - E'_{YY}$$

Row SS Adjusted for Regression

$$(B + E)'_{YY} = (B_{YY} + E_{YY}) - \frac{(B_{XY} + E_{XY})^2}{(B_{XX} + E_{XX})}$$

$$B'_{YY} = (B + E)'_{YY} - E'_{YY}$$

Interaction SS Adjusted for Regression

$$(AB + E)'_{YY} = (AB_{YY} + E_{YY}) - \frac{(AB_{XY} + E_{XY})^2}{(AB_{XX} + E_{XX})}$$

$$AB'_{YY} = (AB + E)'_{YY} - E'_{YY}$$

APPENDIX F

RESULTS OF THE PRE-TEST AND POST-TEST OF CONSERVATION OF QUANTITY BY CLASS

PRE-TEST CLASS A--EXPERIMENTAL

Child Number	Sex	Conservation Tasks[a]				Conservation of Quantity Score
		Liquid	Continuous Solid	Weight	Discontinuous Solid	
1	M	C	C	C	C	6
2	F	N	N	N	C	2
3	F	N	C	C	C	4
4	M	N	T	C	C	3
5	M	C	C	N	C	6
6	F	C	C	C	C	6
7	F	N	C	C	C	4
8	M	N	N	N	C	2
9	M	C	C	C	T	5
10	M	N	N	N	N	0
11	F	N	N	T	N	Absent for post-test
12	M	C	C	C	C	6
13	F	C	C	C	T	5
14	F	N	N	C	C	2
15	F	C	C	C	C	6
16	F	N	N	T	N	0
17	M	N	N	N	N	0
18	M	N	N	N	N	0
19	F	N	N	N	C	2
20	M	N	C	C	C	4
21	M	N	C	N	N	2
						65

[a]C = Conservation response, 2 points.
T = Transition response, 1 point.
N = Non-conservation response, 0 points.

PRE-TEST CLASS B--EXPERIMENTAL

Child Number	Sex	Conservation Tasks				Conservation of Quantity Score
		Liquid	Continuous Solid	Weight	Discontinuous Solid	
1	M	C	T	C	C	5
2	F	N	N	C	N	0
3	F	N	C	C	T	3
4	F	N	N	C	N	0
5	M	N	N	N	N	0
6	M	N	N	N	N	0
7	M	T	N	N	C	3
8	F	C	C	C	C	6
9	M	N	N	N	N	0
10	M	C	C	C	C	6
11	F	T	N	N	C	3
12	F	N	N	N	N	0
13	F	T	N	T	N	1
14	M	C	C	C	N	4
15	M	C	C	N	N	4
16	M	C	C	C	C	6
17	F	N	T	T	T	2
18	M	N	N	N	C	2
19	F	C	C	C	C	6
20	F	N	N	N	N	0
21	M	C	C	C	C	6
						57

PRE-TEST CLASS C--CONTROL

Child Number	Sex	Conservation Tasks				Conservation of Quantity Score
		Liquid	Continuous Solid	Weight	Discontinuous Solid	
1	M	N	C	N	N	2
2	M	C	C	C	C	6
3	M	N	N	C	N	0
4	F	N	N	N	N	0
5	M	C	C	C	N	4
6	M	N	N	C	T	1
7	F	N	N	N	N	0
8	M	N	T	T	T	2
9	F	N	N	T	N	0
10	F	C	C	C	C	6
11	M	N	N	N	N	0
12	F	N	C	C	C	4
13	F	N	N	C	N	0
14	M	N	N	N	N	0
15	M	N	C	C	N	2
16	F	C	N	C	C	4
17	M	C	C	C	C	6
18	M	N	N	N	C	2
19	F	C	C	N	N	4
20	F	C	T	C	C	5
						48

PRE-TEST CLASS D--CONTROL

Child Number	Sex	Conservation Tasks				Conservation of Quantity Score
		Liquid	Continuous Solid	Weight	Discontinuous Solid	
1	M	C	C	C	C	6
2	F	N	N	T	T	1
3	M	N	N	N	N	0
4	F	N	N	N	N	0
5	F	N	C	N	N	2
6	F	N	N	N	C	2
7	F	N	N	N	N	0
8	M	N	N	N	T	1
9	M	N	N	N	N	0
10	F	N	N	N	N	0
11	M	C	C	C	C	6
12	M	N	C	C	C	4
13	M	C	C	C	C	6
14	M	T	N	N	N	1
15	F	N	N	N	N	0
16	M	C	C	C	T	5
17	M	C	C	C	C	6
18	F	C	C	C	C	6
19	F	N	N	N	N	0
						46

POST-TEST CLASS A--EXPERIMENTAL

Child Number	Sex	Conservation Tasks				Conservation of Quantity Score
		Liquid	Continuous Solid	Weight	Discontinuous Solid	
1	M	C	C	C	C	6
2	F	C	C	N	C	6
3	F	N	C	C	C	4
4	M	C	C	C	C	6
5	M	C	C	C	C	6
6	F	C	C	C	C	6
7	F	C	N	C	C	4
8	M	N	T	N	C	3
9	M	C	C	C	C	6
10	M	N	N	N	N	0
11	F	C	C	Absent	--	--
12	M	C	C	C	C	6
13	F	C	C	C	C	6
14	F	C	C	C	C	6
15	F	C	C	C	C	6
16	F	C	C	C	C	6
17	M	C	N	N	C	4
18	M	N	N	N	N	0
19	F	N	N	N	C	2
20	M	C	C	C	C	6
21	M	C	C	C	C	6
						95

POST-TEST CLASS B--EXPERIMENTAL

Child Number	Sex	Conservation Tasks				Conservation of Quantity Score
		Liquid	Continuous Solid	Weight	Discontinuous Solid	
1	M	C	C	C	C	6
2	F	C	T	T	C	5
3	F	C	C	C	C	6
4	F	C	C	C	C	6
5	M	N	N	T	T	1
6	M	C	C	C	C	6
7	M	C	C	C	C	6
8	F	C	C	C	C	6
9	M	N	N	N	N	0
10	M	C	C	C	C	6
11	F	N	T	C	N	1
12	F	C	N	T	T	3
13	F	N	N	N	C	2
14	M	C	C	C	C	6
15	M	C	C	C	C	6
16	M	C	C	C	C	6
17	F	C	C	C	C	6
18	M	C	C	C	C	6
19	F	C	C	C	C	6
20	F	N	N	N	N	0
21	M	C	C	C	C	6
						96

POST-TEST CLASS C--CONTROL

Child Number	Sex	Conservation Tasks				Conservation of Quantity Score
		Liquid	Continuous Solid	Weight	Discontinuous Solid	
1	M	N	N	N	T	1
2	M	C	C	C	C	6
3	M	N	N	N	C	2
4	F	N	C	N	C	4
5	M	C	C	C	C	6
6	M	C	C	C	C	6
7	F	C	N	N	C	4
8	M	N	C	C	C	4
9	F	C	C	C	C	6
10	F	C	C	C	C	6
11	M	N	N	N	N	0
12	F	C	C	C	C	6
13	F	C	T	C	N	3
14	M	N	N	N	N	0
15	M	C	C	C	C	6
16	F	C	C	C	C	6
17	M	C	C	C	C	6
18	M	C	C	C	C	6
19	F	C	N	C	C	4
20	F	C	T	C	C	5
						87

POST-TEST CLASS D--CONTROL

Child Number	Sex	Conservation Tasks				Conservation of Quantity Score
		Liquid	Continuous Solid	Weight	Discontinuous Solid	
1	M	N	N	C	C	2
2	F	T	T	T	C	4
3	M	C	C	C	C	6
4	F	N	N	N	N	0
5	F	N	N	N	N	0
6	F	C	C	C	C	6
7	F	N	N	N	N	0
8	M	C	C	C	C	6
9	M	C	T	T	N	3
10	F	N	N	N	N	0
11	M	C	C	C	C	6
12	M	C	C	C	C	6
13	M	C	C	C	C	6
14	M	N	C	C	N	2
15	F	N	N	N	N	0
16	M	C	C	C	C	6
17	M	C	C	C	C	6
18	F	C	C	C	C	6
19	F	N	C	C	C	4
						69

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