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THE EFFECTS OF TWO SCIENCE CURRICULUM APPROACHES
ON THE ACHIEVEMENT OF SCIENCE KNOWLEDGE
OF ELEMENTARY STUDENTS

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

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The Ohio State University
1973

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# TABLE OF CONTENTS

ACKNOWLEDGEMENTS ................................................................. ii

VITA ...................................................................................... iii

LIST OF TABLES ..................................................................... v

LIST OF FIGURES ..................................................................... vi

Chapter

I. INTRODUCTION ................................................................... 1

  Problem Area
  Statement of the Problem
  Definition of Terms
  Scope and Limitations of the Study
  Summary

II. REVIEW OF LITERATURE AND RELATED RESEARCH .......... 13

  The Literature
  Early History of Elementary School Science
  Influence of Nature Study
  Major Writings Which Influenced Elementary School Science
  The Reform Movement in Elementary School Science
  Process and Content Goals
  Recent Trends in Elementary Science
  The Related Research
  Concept Development
  Children's Science Interest
  Assessing Newer Approaches in Elementary Science
  Summary

III. METHODS AND PROCEDURES ............................................ 42

  Subjects
  Procedures
  The Process Approach
  The Content Approach
  Measurement Instruments
  Statistical Design of the Study
  Summary
IV. ANALYSIS OF THE DATA ........................................ 63

Introduction
Means and Standard Deviations
Interaction of Intelligence and Sex
Interaction of Instructional Approach and Intelligence
Intelligence
Sex/Process - Content
Process - Content Groups
Summary

V. SUMMARY AND CONCLUSIONS .................................. 79

Purpose
Procedures
Summary of Findings
Discussion and Interpretations
Conclusions
Recommendations for Further Study

APPENDIX

A. Tukey H.S.D. Test Calculation for Interaction of Sex and Intelligence ........................................ 93

B. Tukey H.S.D. Test Calculation for Interaction of Treatment and Intelligence ................................ 95

C. Measurement Instrument ..................................... 97

BIBLIOGRAPHY ....................................................... 109
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Summary of Comparable Characteristics of the Two Groups of Test School Populations</td>
<td>44</td>
</tr>
<tr>
<td>2</td>
<td>Random Selections for Data Matrix</td>
<td>45</td>
</tr>
<tr>
<td>3</td>
<td>Means and Standard Deviations of Student Performance by Treatment, Intelligence, and Sex on the STEP Test</td>
<td>64</td>
</tr>
<tr>
<td>4</td>
<td>Analysis of Variance of Student Performance by Treatment, Intelligence, and Sex on the STEP Test</td>
<td>66</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>1</td>
<td>Living Things, Plants and Animals</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>Non-Living Things: The Earth and the Universe</td>
<td>51</td>
</tr>
<tr>
<td>3</td>
<td>Non-Living Things, Matter and Energy</td>
<td>52</td>
</tr>
<tr>
<td>4</td>
<td>Interaction of Intelligence and Sex</td>
<td>67</td>
</tr>
<tr>
<td>5</td>
<td>Results of Tukey H.S.D. Post Hoc Analysis on Ordered Means on the Interaction of Sex and Intelligence</td>
<td>69</td>
</tr>
<tr>
<td>6</td>
<td>Interaction of Treatment and Intelligence</td>
<td>72</td>
</tr>
<tr>
<td>7</td>
<td>Results of Tukey H.S.D. Post Hoc Analysis on Ordered Means on the Interaction of Intelligence and Treatment</td>
<td>73</td>
</tr>
</tbody>
</table>
CHAPTER I

Introduction

Problem Area

The many new elementary science programs which have been developed within the last ten to fifteen years can generally be grouped into two broad classifications: those which are structured primarily on the development of important science concepts and those built primarily around the development of science processes. The first is based on the acquisition of scientific knowledge—facts, principles, generalizations, laws; the second, on the development of scientific methodology—observing, classifying, measuring, experimenting.

There is concern by some in education that children learning science through process development do not learn the science facts deemed necessary for scientific literacy. On the other hand, there are those who believe that the only way to learn science is through participating as a scientist. However, there is reason to believe that children taught science through a process-oriented curriculum can achieve scientific knowledge comparable to children taught through a content-oriented curriculum. Partin's (1967) study would suggest that this is true since one of the conclusions in her study of achievement of fourth grade content/process pupils was that neither method proved superior.
Taba (1962, pp. 172-173) points out that the controversy between content and process learning has been one of long standing throughout the history of curriculum making. She indicates that only one of the two characteristics of a subject, content or process, has been emphasized to the detriment of the other. One viewpoint as she sees it is that content per se is important. According to this view, each bit of the subject, each minute fact is "...precious knowledge... and skipping as much as an iota of it leaves a gap in the educational edifice and in the background of the students." The other viewpoint as she describes it is "...The modern concept of mental discipline is more analytical and more likely to be concerned with scientific or critical thinking, the ability to solve problems, and the capacity to understand and to pursue the methods of inquiry."

Atkin (1966-67) believes that the controversy between content and process instruction is particularly highlighted in science education where the debate has been going on for many years but has reached new dimensions because of the new projects that appear to be based almost entirely on process. The educational change and reform movement which had its beginnings in the years immediately following World War II had its effects on this controversy, according to Goodlad (1966) and Ellena (1973). Goodlad goes on to point out that even though the reform period was not "significantly robust" until after the launching of Sputnik in 1957, the shocking inadequacies in science and mathematics as revealed by the young men recruited for military service during World War II motivated some scientists and mathematicians to turn their attention to the problem. Their subse-
quent involvement was a factor in producing change; some scholars stressing content or knowledge mastery, others emphasizing inquiry or process skill development. As knowledge piled up at an intimidating rate the academicians working on pre-collegiate programs were providing curriculum with what was considered as needed infusions of content and process.

Gagné (1961) points out that the process approach has in it a little of both of what he calls the "content" and the "creativity" approaches. Opponents insist that any content is scant and unconnected with any concept development, but Gagné goes on to state that concentration on any particular science is not enough, for the child must learn the processes in a systematic manner if transferability is to be developed in the child for continued learning in science.

Atkin (1966-67), an articulate opponent of the process approach, believes that, as a rule, scientific training and research alone do not equip one particularly well to analyze science in general terms. He asserts that the basic flavor of the process approach is the apparent assumption that science is a "common-sensical" activity and that the appropriate skills are the primary ingredient in doing productive work. In protest he insists that within science there must be the explicit recognition of the powerful role of conceptual frames of reference within which scientists and children operate. Ausubel (1966-67) supports that position by stating:

In my opinion, any science curriculum worthy of the name must be concerned with the systematic presentation of an organized body of knowledge as an explicit end in itself. Even if it is relatively superficial and organized on an intuitive basis, as it must be in the elementary school, the science curriculum
should make a start in this direction and give the student a feeling for science as a selectively and sequentially organized structure of knowledge (p. 3).

Even though the controversy exists between the process and content approaches, most scientists and educators agree with Ausubel's (1966-67) point of view that what is needed is a more balanced approach to science education. He states that learning by discovery is essential for imparting knowledge about science processes but expository instruction is the only feasible method to transmit content. Blackwood (1964) believes that a rich science program involves children in the entire spectrum of ways of investigating and is planned so that children's learning activities are focused on gaining understandings of selected content to be used as intellectual tools for dealing with new problems.

**Statement of the Problem**

There seems to be little research, particularly for those using a process-oriented curriculum approach such as *Science - A Process Approach*, which compares the effectiveness of two science curriculum approaches, content and process, on the achievement of science knowledge. There is a need for research to determine if process-taught students do learn science content. If students do learn science knowledge as they develop skills in using science processes, this should be reflected in some way in the achievement of the students.

The central purpose of this study, therefore, was to determine whether fifth grade students taught by a science process approach
for five years achieved a comparable degree of science knowledge to fifth grade students taught by a content approach for five years. To determine the effectiveness of the curriculum approaches on the achievement of scientific knowledge by the students, a standardized testing instrument, Sequential Tests of Educational Progress: Science, was used.

In this study the experimental group consisted of sixty fifth grade students selected randomly from the two hundred sixty-seven fifth grade students from four Lakewood (Ohio) Public Elementary Schools using Science - A Process Approach for five years, grades 1-5. As participants in the process methodology of Science - A Process Approach, these students were taught to use selected processes of science: observing, using space/time relationships, using numbers, measuring, classifying, communicating, predicting, inferring, defining operationally, formulating hypotheses, interpreting data, controlling variables, and experimenting. They were helped to acquire and practice these processes of science as intellectual skills in a manner that would aid them in their future learning in science as well as in other areas. The students learned these skills in a hierarchical manner—later learning building upon earlier learnings. Success did not depend on skill in reading or acquiring a mass of facts but, rather, on the student's ability to use the processes of science. The time schedule allocated for process approach instruction was the same as for all science instruction as prescribed by the Lakewood (Ohio) public Schools. This was equivalent to eleven weeks of science (exclusive of health), five days per week, ranging from 40 minutes
per day in grade 1 to 60 minutes per day in grade 5. Supervision of
the program through the school principal and the coordinator of
elementary science was comparable to all science supervision.

The control group consisted of sixty fifth grade students
selected randomly from the three hundred sixteen fifth grade stu-
dents from four Lakewood (Ohio) Public Elementary Schools using a
content approach to science instruction as published by the Lakewood
(Ohio) Public School System for five years, grades 1-5. This con-
tent approach is simply entitled Science: Grade One; Science:
Grade Two, etc. and is elaborated on more fully in Chapter III.
As participants in the content approach of science curriculum, these
students were guided toward a comprehensive and sequential under-
standing of the topical framework characteristic of the recognized
science fields. These topics in the Lakewood program include:
living things — plants and animals, non-living things — the earth
and the universe, and matter and energy. Each of these controlling
topics was supported by numerous sub- or instructional concepts.
Through this approach the students were helped to acquire scientific
knowledge — facts, principles, generalizations and laws — in order to
gain mastery of the subject. Also, they were helped to gain a
feeling for science as a selectively and sequentially organized
structure of knowledge. The time schedule allocated for content
approach instruction was the same as for all science instruction as
prescribed by the Lakewood Public Schools as described in the pre-
ceding paragraph. Supervision of the program through the school
principal and the coordinator of elementary science was comparable
to all science supervision.

During the eighth month (April) of the students' fifth grade year and, after five years of learning science through a content or process approach as briefly described heretofore, and in more detail in Chapter III, grades 1-5, those students randomly selected to participate in the study were tested using the Sequential Test of Educational Progress: Science (STEP), Series II, Form 4A, 1969. At the time, this instrument was selected as the best available measurement tool to judge science knowledge. This standardized test was used to determine whether fifth grade students, taught by a science process method for five years, achieve science knowledge comparable to fifth grade students taught by a content method for five years. In analyzing the data, students were blocked by intelligence (high/low) and nested on sex (male/female) to determine differential effects from the use of a content or process approach on sex or intelligence as well as to determine the interactive effects of treatment, sex, and intelligence. Analysis of variance procedures were employed to analyze the data obtained. Such analysis permitted the assessment of the following hypotheses:

1. There will be no differences in the achievement of fifth grade students in science knowledge as measured by Sequential Tests of Educational Progress: Science (hereafter referred to as STEP) between the groups instructed through a process-oriented approach and the groups instructed through a content-oriented approach.
2. There will be no differences in the achievement of fifth grade boys in science knowledge as measured by STEP between process-taught boys and content-taught boys.

3. There will be no differences in the achievement of fifth grade girls in science knowledge as measured by STEP between process-taught girls and content-taught girls.

4. There will be no differences in the achievement of process-taught fifth grade boys in science knowledge as measured by STEP and process-taught girls.

5. There will be no differences in the achievement of science knowledge of low-intelligence, process-taught fifth grade students as measured by STEP and low-intelligence, content-taught students.

6. There will be no differences in the achievement of science knowledge of high-intelligence, process-taught fifth grade students as measured by STEP and high-intelligence, content-taught students.

**Definition of Terms**

Throughout this study, several terms will be used frequently which require definition:

**Concept**: An idea or aggregation of ideas that has been acquired as a symbol or generalization of the common element (Good, 1959). A generalization about related data (Russell, 1956). A relatively complete and meaningful idea in the mind of a person (Woodruff, 1964).
Content: Subject matter including facts, information, knowledge, principles constituting the substance of any course of study to be acquired by the learner (Good, 1959).

Knowledge: The accumulated facts, truths, principles and information to which the human mind has access (Good, 1959).

Process: Specific skills of critical inquiry such as observing, classifying, and measuring (Blanc, 1967). A procedure in which principles, laws, or generalizations are developed using specific skills such as classification, examination, and verification (Good, 1959).

Inquiry: Specific skills and methods to make systematic studies and find out why (Suchman, 1960). The operations of data-gathering, data-organizing, and data-using (Fielder, 1971).

High Intelligence: Those students with I.Q.'s 115 and above as measured by the California Test of Mental Maturity and classified as superior or very superior by the test maker, California Test Bureau, as descriptive classifications based on the normal population and an I.Q. standard deviation of 16 (Sullivan, Clark, & Tiegs, 1957).

Low Intelligence: Those students with I.Q.'s 99 and below as measured by the California Test of Mental Maturity and classified as low average, inferior, or very inferior by the test maker, California Test Bureau, as descriptive classifications based on the normal population and an I.Q. standard deviation of 16 (Sullivan, Clark, & Tiegs, 1957).
Scope and Limitations of the Study

The study was carried out in the Lakewood (Ohio) Public School System. The Lakewood (Ohio) Schools are located in an all white, urban-suburban, residential community of about 73,000 persons, bordering on Cleveland's western boundary. Once regarded as a wealthy suburb, Lakewood is now a middle-income community. Only about 16 per cent of the residents are professional persons. Other classifications include skilled, semi-skilled, semi-professional and clerical. Two-thirds of the dwellings are rental properties which lend themselves to a more transient population. Lakewood has always been noted for its quality schools and still retains a high rating as a leading school district. The subjects for the study came from eight of the ten elementary schools which had a total population of about five thousand students. The median I.Q. of the students from the schools selected ranged between 107 and 111, depending on test and grade placement. Achievement scores ranged from the 60th percentile to the 70th percentile, depending on test and grade placement. The results of the study can only be generalized to a like population of fifth grade students who had the full five year period of content or process curriculum.

The study was designed to determine the relationship of achieved scientific knowledge between content- and process-taught fifth grade students acquired over five years of elementary schooling, grades 1-5, as measured by a standardized instrument. Therefore, the scope of the study was limited to the investigation of acquired science knowledge only and no attempt was made to assess
the subjects' knowledge of science processes. Further, the study was limited to only those students instructed through either approach for a full five years, grades 1-5, in the Lakewood (Ohio) Public Schools.

The subjects of the study were randomly selected and, therefore, all extraneous factors such as attitudes about school or science education, school attendance, individual self-concept, motivational factors, physiological or psychological impairments and disorders, and different parent, sibling and peer-group situations were pre-equated by the randomization process.

Study of the research documents of the Lakewood (Ohio) Public Schools in such areas as intelligence and achievement, new family characteristics, Federal aid distribution like Title I, and dropout records showed the control and experimental samples to be similar to each other as to socio-economic condition, ability, and educational development as illustrated in Table 1, Chapter III.

It must be assumed that all teachers involved with the students of the study groups adhered to the prescribed time schedule for the teaching of science as prescribed by the Lakewood Public Schools during the five year period. Further, that these same teachers did execute the plan of science curriculum as prescribed by the Lakewood Public Schools. These factors were pre-equated by the randomization process.

There are many limitations and assumptions which are basic to the use of a standardized test instrument such as its true validity and reliability and the conditions under which it is administered.
In the study, it is assumed that the test used actually measures the content or knowledge of science as purported by the publisher and reviewers in the *Sequential Tests of Educational Progress Series II Handbook*.

**Summary**

By the nature of the educational dilemmas being faced today in accountability, educational reform, and curricular approach in science education, there appeared to be a need for more definitive research to add to the limited, existing evidence that students instructed by a process approach in science education could acquire comparable scientific knowledge as students taught by a content approach. The purpose of the study was achieved by analyzing the data collected from the use of a standardized science test given to two randomly selected groups of fifth grade students who either had been taught science by a process approach over a five year period during their elementary schooling or by a content approach under like conditions.

Chapter II will contain a review of the pertinent literature and research related to science education, curriculum reform, and the content/process controversy. Subjects, instruments, and procedures used in the study will be described in Chapter III. The data will be presented and interpreted as findings in Chapter IV. Chapter V will include a summary of the findings, conclusions, implications and recommendations for further research.
CHAPTER II

Review of Literature and Related Research

The Literature

Early History of Elementary School Science

The teaching of science in the elementary school can be considered a relatively recent development even though its history can be traced back over more than one hundred years (Bradley, Earp, & Sullivan, 1966; Smith, 1963). While the teaching of scientific facts in the secondary schools in America began with Benjamin Franklin's Academy, elementary teachers continued to feel that their energies had to be expended in promoting learning in "Readin', Ritin', and 'Rithmetic" and, therefore, the elementary schools were slow in developing science courses. In fact, prior to 1950, science in the elementary school consisted mainly of nature study. It was after 1950, for the most part, that "...children were being taught to develop 'science mindedness' (Bradley, et al, 1966, p. 153)." These authors said of the sixties:

Science has joined the three R's as the fourth cornerstone of the curriculum.... Research studies indicate that the ages eight to twelve are ideal for teaching some basic principles to children.... Educators are finding that children are capable of learning more science than was included previously in the elementary curriculum (p. 154).

Elementary school science has been researched as far back as the decade of the 1850's by Herbert A. Smith in his article "Educa-
tional Research Related to Science Instruction for the Elementary and Junior High School: A Review and Commentary" (1963). According to Smith (1963), two of the earliest influences in the 1850's were the didactic literature approach directed to children's observation and the study of natural phenomena as reported by Underhill in 1941. The other as reported by Shoemaker in 1930 was the Pestalozzian object teaching movement which was implemented in Germany as community study and in England and the United States as nature study. The latter method became known as the Oswego method, according to Lammers due to its development at Oswego, New York, and to the influence of the newly formed National Education Association in 1857. This became the accepted method of science teaching in the country's rapidly growing elementary schools (Kuslan & Stone, 1968).

Elementary school science was again catapulted to greater importance in the curriculum during the decade of the 1870's. Kuslan and Stone (1968) and Smith (1963) point out that this was due mainly to Herbert Spencer's essay, *What Knowledge Is of Most Worth* of 1860 and the growing importance of science and technology in society. Colleges and universities soon came to accept science subjects as prerequisites for admission. During the depression of 1873, the program of the public schools, particularly the elementary schools, were the object of abusive criticism. Old patterns of teaching and learning were seen ill-adapted to changing times. Tax-conscious citizens were demanding clarification of the aims and purposes of education with one hue and cry being for more science in public school programs.
Near the end of the nineteenth century the National Education Association sponsored a study by the Committee of Ten which was to influence the entire educational system. Even though this extensive study was aimed at the secondary level, the influence and changes were quickly reflected in the elementary schools. The report stabilized science offerings, put emphasis on laboratory use and other direct experiences, promoted special training for teachers of science and, most importantly, influenced the development of science textbooks, syllabi and other instructional material which began to appear in an appreciable volume thereafter (Ebel, Noll & Bauer, 1969; Smith, 1963).

The Committee of Fifteen established by the National Education Association in 1895 "...asserted that science was indispensable in the elementary schools because mastery of science method was a key to success in life (Kuslan & Stone, 1968, p. 120)."

Influence of Nature Study

Around the turn of the century, a number of men had great influence on the field of elementary school science according to Craig, 1957; Lammers, 1955; and Underhill, 1941 (Ebel, Noll & Bauer, 1969; Kuslan & Stone, 1968; Smith, 1963). William F. Harris first translated philosophy and educational theory into a specific and extensive elementary school science curriculum. The philosophical works of G. Stanley Hall and Colonel Francis W. Parker influenced the detailing of elementary science programs in the area of nature study. The use of science as a unifying principle in the elementary school was prompted by the work of Henry H. Strait and Wilbur S. Jackman at the
Practice School of the Cook County Normal School and now the School of Education of the University of Chicago. Even though Jackman's work was obscured for a time by the extended development of the nature study movement, his writings represent a connecting link between writers of children's literature and modern elementary science.

Liberty Hyde Bailey at Cornell was a prime mover of the nature study movement. He and his colleagues were motivated by the need to improve agriculture and to halt the increasing migration of young people from the farms to the cities. One of the more important publications to come out of Cornell was the *Handbook of Nature Study* by Anna Botsford Comstock. The delimiting factor of the Cornell works was the lack and perception of child understanding by specialists in science who considered the child in terms of his limitations rather than his capabilities.

The enthusiasm for nature study began to wane by the 1920's (Ebel, Noll & Bauer, 1969; Smith, 1963; Victor & Lerner, 1967). New designs in science curricula were beginning to have their influence. Men such as Charles Sanders Pierce, William James, and John Dewey were having tremendous influence on education which was particularly relevant to science instruction. Pierce's work provided the link between concept and experience. Dewey's contributions were numerous but none more important for the developing field of elementary science than his contention that the methodology of science was at least equal or perhaps of greater value than the actual knowledge [certainly a significant influence on the present emphasis of science as inquiry]. It was apparent by the mid-twenties that nature study was no longer a satisfactory
vehicle for a modern science program. Its whole rationale was no longer consistent with the philosophy, psychology, and methodology of the times. It was inconsistent with the existing social and economic realities.

**Major Writings Which Influenced Elementary School Science**

According to Ebel, Noll & Bauer (1969), Kuslan & Stone (1968), Lammel (1971), and Smith (1963), Craig's thesis at Columbia in 1927 was one of the landmarks in elementary science and was basic to most later writings, including his own. The study was done at the famous Horace Mann Laboratory School at Columbia University and was entitled *Certain Techniques Used in Developing a Course of Study in Science for the Horace Mann Elementary School*. Craig turned away from the nature study movement and, in so doing, took note of the great chaos in educational goals to which lip service was then being paid. Craig saw the function of science in the elementary school to be significant in terms of general education pointing out that the laws, generalizations, and principles of science have vital meanings to individuals regarding numerous questions which confront them. Together with his co-workers they envisioned elementary school science as a balanced program of the major science areas systematically organized around the important concepts. He saw a utilitarian aspect as it was related to health, safety, and the economy. He was also aware of more than the cognitive aspects of science instruction and emphasized the affective dimensions as well. Perhaps Craig's study has had the most far-reaching influence on the development of elementary science of any
single event in the history of the field, according to most writers.

The Thirty-first Yearbook of the National Society for the Study of Education published in 1932 was another influential step in the continuing development of elementary school science (Ebel, Noll & Bauer, 1969; Kuslan & Stone, 1968; Smith, 1963). The yearbook presented several major thrusts which included the following: the concept of integrated science teaching, a trend which has continued to be emphasized down to the present time; an emphasis on the major generalizations of science as objectives of instruction which has had profound effects on courses of study and textbooks; research devoted to identifying major principles of science which were significant to general education and which was influential on the subsequent research done in science education; definite and clear support for elementary science rather than nature study which contributed to the rapid advancement of science at the elementary school level; and, finally, advocating that the basis for the selection of science content be on personal and social criteria which conformed to and augmented the educational thinking that was then developing.

As reported by Ebel, Noll & Bauer (1969) and Smith (1963), the Forty-sixth Yearbook of the National Society for the Study of Education, 1947, was also devoted to the problems of science education. This followed closely the end of World War II, a period in the world's history in which the technological and scientific advances made by man were of the greatest proportions known to that time (Obourn, 1961; Trump and Baynham, 1961; Hurd, 1964; Russell, 1965; Anderson, 1966, pp. 3-9; Goodlad, 1966, pp. 11-20; Edwards, 1972, pp. 282-299)
[now exceeded by the rapidly doubling advances in all fields of knowledge today.] The increasing impact of science upon the social, cultural, and economic affairs of man continued to be very much in evidence in the thinking revealed in this yearbook. The following quotation taken from the Forty-sixth Yearbook (Smith, 1963) is illustrative of this fact:

Instruction in science must take cognizance of the social impact of developments produced by science. It is not enough that they be understood in technical or scientific sense; it is most important that their effects on attitudes and relationships of people be studied and understood. Science instruction has not only a great potential contribution to make but also a responsibility to help develop in our youth the qualities of mind and the attitudes that will be of greatest usefulness to them in meeting the pressing social and economic problems that face the world (p. 1).

In this yearbook there was a marked sensitivity to some of the affective objectives of science instruction. There was also a notable change in the responsibility which educators had to translate their oft intangible and illusive objectives into practical programs and to determine how the effectiveness of instruction could be measured.

As cited by Smith (1963), the Fifty-ninth Yearbook, 1960, of the National Society for the Study of Education took an increasing cognizance of the dependence of society on science and the training of citizens of such a society of fundamental importance. The yearbook also stresses the process or inquiry characteristic of science, such as the following:

One function of the elementary school has always been to help children learn a part of what they need to know from the world's storehouse of knowledge. In recent years this function has embraced more and more science. Scientific methods of investigation, by which knowledge may be acquired and tested, are now very much a part of our culture. The elementary school
should help children become more acquainted with these methods (p. 112).

The Reform Movement in Elementary School Science

Revolutionary changes have been taking place in the teaching of science since the mid-fifties (AAAS, 1970; Dunfee, 1967; Ebel, Noll & Bauer, 1969; Ellena, 1973; Lammel, 1971; Victor & Lerner, 1967). Teams of scientists and teachers have attempted to bring about far-reaching improvements in science education at all levels, including the elementary school level. During the period from 1930 to about 1955, there was a consolidation and refinement of the viewpoint about science education that placed considerable stress on the social utility of the subject. The recent trend, a negative reaction to the social utility approach, began to be articulated in the fifties (Ebel, Noll & Bauer, 1969). The distinguishing characteristics of the wave of curriculum reform in science generated during this period can be attributed to the fact that academic scientists were involved in curriculum development activities. Scientists had a major influence in increasing the awareness of the need for change in science programs. Many have been active and effective in interpreting science and its modes of inquiry and in designing new learning experiences and instructional materials that are in keeping with contemporary science.

According to Lammel (1971), the curriculum reform movement in science was initiated at the secondary level but quickly included science programs from kindergarten on up. A number of scientists who had turned their attention to the then-current programs in elementary
school science did not like what they found and expressed harsh criticism in such an evaluation as made by Seaborg in his article "New Currents in Chemical Education" in 1960 (Lammel, 1971):

Many persons and committees have reviewed the content and effectiveness of science courses presented in elementary schools and have not found a healthy situation....

Of all weaknesses found, perhaps the greatest is the almost complete lack of correlation between science as presented in school and science as understood by the scientist. Elementary school science is primarily a pictorial science... with snippets of information about such favored topics as weather, nature study, magnets, and a series of 'Gee Whiz' topics. It is not well organized and does not reveal strong underlying connection between all natural phenomena. It is not presented in a logical progression of interrelated topics increasing in difficulty. Topics are presented as results to be accepted on faith. There is little exposure to experimentation and little attempt to indicate how scientific conclusions are derived by inductive or deductive logic (p. 124).

To determine whether the nation should undertake a concerted effort of curriculum improvement in elementary school science, the American Association for the Advancement of Science, with the financial aid from the National Science Foundation, sponsored three regional conferences, in 1961, of scientists, teachers, school administrators, and psychologists to consider the following aspects of science instruction: present policies, practices, and materials; recent efforts to create new courses for senior high schools; and recent experiments in teaching young children. The conferences reached the following conclusions: Instruction in science should be a regular part of the curriculum from kindergarten through grade nine (and beyond, but the conference considered only these grades); a major effort should be undertaken, and this effort should involve improving both course materials and classroom teaching (Ebel, Noll & Bauer,
Some points of substantial agreement as reported by the steering committee of AAAS in 1961 were (Karplus & Thier, 1967):

1. Science should be a basic part of general education for all students at the elementary and junior high levels.
2. Instruction at the elementary levels should deal in an organized way with science as a whole.
3. There must be a clear progression in the study of science from grade to grade.
4. There should be no single, national curriculum in science.
5. Science teaching should stress the spirit of discovery characteristic of science itself.
6. New instructional materials must be prepared for in-service and pre-service programs for science teachers.
7. The preparation of instructional materials will require the combined efforts of scientists, classroom teachers, and specialists in learning and teacher preparation.
8. There is great urgency to get started on the preparation of improved instructional materials for science (pp. 2-3).

Ronald Gross, Assistant to the President of the Academy for Educational Development, described the common elements of the radical innovations challenging American education in the mid-sixties (Karplus & Thier, 1967):

First, they have been initiated by distinguished university scholars rather than by professional educators.... In the heyday of progressive education, it was the educators, especially the educational psychologists, who took charge. In the current reform movement, the academic scholars made the first move. It is significant, though, that in trying to plant their specialists in the terra incognita of the ordinary classroom, the scholars found they needed all the light that contemporary psychology and related disciplines could provide.

Second, the major reforms have been created outside the educational establishment of state departments of education, teacher-training institutions, professional curriculum committees, and commercial textbook publishers. The curriculum revisions are national in scope and support, if not in actual application....

Third, though the machinery of the educational establishment has been bypassed, the movement has won the support and enthusiasm of a great many practicing teachers and school administrators. Thus, the programs signal an unprecedented collaboration between academic scholars and schoolmen - the
most hopeful outcome to date of the recent rapprochement of the
two groups.

Fourth, the reformers have not merely issued dicta on what
and how to teach. The scholars have gone into the classrooms;
y they have brought real children and seasoned teachers into
their laboratories; and, together, they have oriented, tested,
and revised materials and methods that will succeed in the
schools.

Fifth, the most promising of the programs, whatever their
particular form, draw from two broad streams of enlightenment:
new understanding of the basic elements of each subject and
new or freshly interpreted understanding of the capacity for
learning inherent in youngsters (pp. 3-4).

The reform movement recognized that science learning at the
elementary school level required the active involvement of children.
The elementary school classrooms had to become "...laboratories as well
as study halls, and the school environment must be used for field
studies as well as for recreation (Karplus & Thier, 1967, p. 4)."
Actually, this idea was not new in science education but no place in
its history was it ever implemented on a significant scale. "By and
large, what existed in the name of elementary science was a reading pro-
gram (Karplus & Thier, 1967, p. 4)."

Since the mid-sixties many science curriculum reform groups
have been active in curriculum revision for the elementary grades
(Lammel, 1971). This movement has accelerated into the early seventies
in spite of the fact that several of the reform groups have been phased
out because their trial periods had run out; others had completed
their plans; and others were being made available through commercial
distributors.

Among the more significant projects of this reform period, at
least four have developed considerable interest on the part of educa-
tors and have had the most influence. These include the work of the
Commission on Science Education of the American Association for the Advancement of Science, whose project is known as Science—A Process Approach; the Science Curriculum Improvement Study of the University of California; the Elementary Science Study of the Educational Development Center [formerly Educational Services, Inc.]; and the Minnemast Project of the University of Minnesota (Ellena, 1973).

**Process and Content Goals**

Two major strands of purpose have emerged from the experimental projects for the teaching and learning of science; those goals dealing with the processes of inquiry and those goals pertaining to the knowledge dimension. The process goals emphasize the need for all learners to participate actively in genuine inquiry; children to be involved in investigating, experimenting, and discovering, through which they learn not only to think and to grow in intellectual self-direction but also to derive joy from learning. The product goals of science pertain to the acquisition and understanding of scientific knowledge and the fundamental principles of science; children are involved in the understanding of the major ideas of science in order to develop literacy in science (Brandwein, 1966; Piltz, 1970). The learning theories of Bruner (knowledge of process and importance of structure), Gagné (sequence of learning materials), Piaget (level of maturity) have played an important role in the emphasis given to process instruction and the recent development of process-oriented science programs (Ellena, 1973).

One of the purposes of the reform movement in science has been
to have students learn about and use science as a scientist; to behave like a scientist. The easiest way to learn science in the classroom is to use both goals, process- and product- goals. Ideally, these two strands of purposes should be closely bound together in the science-learning process. One without the other, or undue emphasis on one to the disadvantage of the other, may inhibit the evolution of a significantly balanced program (Lammel, 1971).

The Science Curriculum Improvement Study developed at the University of California, Berkeley, is an example of the product-goal emphasis in that its direction centers on the identification of fundamental science concepts. The curriculum designers constructed the program around a relatively small number of basic scientific ideas such as the use of the systems concept in understanding scientific events, the relativity of position and motion, and interaction among objects (Karplus & Thier, 1967).

The AAAS project, Science - A Process Approach, is an example of the process-goal in that its direction centers on the processes used by scientists and not on the fundamental "features" of science [concepts]. Scientific processes such as classification, measurement, observation, and inference were included in the design of the curriculum (Gagné, 1966).

Other innovations in elementary science blended the two goals, process and concept, into a single curriculum. The Elementary Science Study Group designed a curriculum that encouraged independent investigation [process] within a conceptual framework directed toward learning fundamental science principles [concept] (Hawkins, 1964, 1965).
Recent Trends in Elementary Science

As pointed out by Atkin (1971), even though the innovations of the mid-sixties carried over into the seventies, there have been new pressures for curriculum reform brought about by societal needs that differed from earlier requirements to educate gifted children to supply scientists and engineers. Problems associated with race and poverty came to the forefront of American educational concerns. New programs focused on teaching all children, regardless of economic background or race, the basic concepts and skills of science.

According to Atkin (1971), a new model for curriculum development emerged in the late sixties—the industrial engineering approach. It was believed that the construction of a curriculum was analogous to the construction of an airplane or an automobile; specifications are first delineated, then the product is designed. This led to the whole movement of teaching by instructional, performance, or behavioral objectives (Gagné, 1965; Glaser, 1962; Mager, 1962; Ofiesh, 1965; Popham, 1970; Skinner, 1954).

In curriculum development, performance objectives are first identified, then the program is designed to assure that the children will be able to perform the desired behavior. Part of the motivation behind this approach was a desire by educators to design programs that would enable every child, whatever his background, to achieve his potential.

Generic terms for instructional programs based on the engineering model are Individually Prescribed Instruction (IPI), Individually
Guided Education (IGE) and others. In this instructional approach, sequential educational programs are designed to enable each child to move at his own pace and, hopefully, according to his own style. The AAAS program, Science - A Process Approach was a program which anticipated the IPI trend of a tightly ordered, elaborately prescribed, and highly sequential approach to curriculum design in elementary school science (Gagné, 1966).

Prescriptive teaching [based on the engineering model], to insure that learning [a change in behavior] has taken place and that students have met the objectives with success [accountability] is the "...watchword for the 70's", according to Morris (Sciara & Jantz, 1972). Almost by accident, many of the curriculum designs of the sixties were structured in a manner which lent themselves to the thrust of accountability in the seventies. The concept of accountability is based on specifically defined objectives, measurement techniques which spell out exactly what the teacher intends to accomplish, instructional methods that guarantee most students will obtain the objectives, and a responsibility by teacher, administrator, or school system for the success or failure of the schools or students (Sciara & Jantz, 1972).

As pointed out by Ellena (1973) and Norris (1969), one accountability model in science education has been the National Assessment of Educational Progress in the science section. The four primary objectives of science education to be used as the basis for national assessment [accountability] as developed by the contractors assigned to this project were (Norris, 1969):
Objective I. Know the fundamental facts and principles of science.

Objective II. Possess the abilities and skills needed to engage in the processes of science.

Objective III. Understand the investigative nature of science.

Objective IV. Have attitudes about and appreciation of scientists, science, and the consequences of science that stem from adequate understandings (pp. 5-6).

Descriptions of typical behaviors expected for different age groups under these objectives are delineated in the completed national assessment material. The delineations are, in general, written in terms of what about half the students at a given age level might be expected to know or be able to achieve. This type of accountability model more clearly emphasizes to teachers and supervisors the importance and need for the formulation of course objectives and daily behavioral objectives. As pointed out by Ellena (1973):

The classroom teacher must formulate specific objectives in three domains: (a) the cognitive (mental and intellectual processes of the learner), (b) the affective (appreciation, attitudes, emotions, and interests of the learner), and (c) the psychomotor (neuro-muscular and physical skills) (p. 301).

As pointed out by Morris in 1971 (Sciara & Jantz, 1972), accountability is not new to education even though the term in connection with teacher performance did not appear in the Education Index until June, 1970. Education has always been accountable to someone or some constituted authority. According to Sciara & Jantz (1972, p. 3), however, the age of accountability has dawned on American education and probably will be the most important educational movement in the decade of the seventies. Morris (Sciara & Jantz, 1972) points out some of the reasons for this current emphasis as follows:
First, criticism and reform movements seem to wax and wane in relation to the current social milieu... [the "roaring twenties" and depression eras].

Second, criticism and reform movements follow a shocking event in which we tend to come out second best... [the post sputnik era].

Third, since the schools are considered to be second only to the family in terms of safeguarding and extending traditional values, they are especially susceptible to attacks during times when these values are disappearing and new values to fill the vacuum have not been born... [youth searching for identity in periods of uncertainty and confusion].

Fourth, schools are supposed to prepare leaders who are able to solve many of the pressing social, political, and economic problems which confront a nation... [national and world problems are directed toward education].

Fifth, the general state of the economy, coupled with the social factors already mentioned, is a major cause of the current emphasis on accountability... [militancy toward inflation and tax increases].

Sixth, there is widespread agreement that something is basically wrong with public education. Too many students cannot read, are deficient in basic communication skills, quit before completing the twelfth grade, and seem unpatriotic.

Seventh, today more parents are better educated because they have attended high school and college. They judge the progress of their children on the basis of their experiences and the widely publicized advancements in educational technology. They see the realities of the educational dilemma and are becoming more critical of and less willing to believe educational authorities. They are demanding that administrators and teachers be more accountable for the progress of students (pp. 20-21).

As discussed by Governor Milliken of Michigan in 1970 (Sciara & Jantz, 1972), accountability may mean something a little different to each person individually but there is a common implication. The chief implication is that the people of this nation are demanding to know what their children are learning, why they are being taught whatever it is they are being taught, and how well they are learning what it is they are supposed to be learning.
The Related Research

Concept Development

Although there is much yet to be discovered about children's learning of science, research of the recent past and that which is going on in newly developed curriculum projects is revealing more and more about factors that affect learning. Two facets, children's science interest and their concept development, seem to have become the focus of considerable research.

Suchman (1960) was concerned whether or not skill in inquiry could be taught to elementary school children, using science as the content vehicle. He believed that pupils could be taught to attack, through a series of yes or no questions, a scientific problem posed by a science demonstration shown without comment on film. Pupils were trained to formulate questions to determine the parameters of the situation viewed, to determine the relevance of certain conditions and to verbally experiment to test hypotheses. Suchman concluded that fifth grade pupils can improve their skills in inquiry and become more productive in their use of questions. On the other hand, he concluded that pupils have little interest in the method for itself, their desire to understand the problem situation being the chief motivating factor in their performance. There were, however, increments in understanding of content as skills of inquiry developed.

Butts and Jones (1966) used Suchman's inquiry training technique with sixth graders as the method of instruction to discover whether or not these children evidenced improved problem-solving
ability; whether or not intelligence, sex, chronological age, and factual knowledge were related to improved problem-solving behavior; and whether or not those children who showed improved problem-solving behavior showed meaningful concept development. The researchers found a relationship between inquiry training and positive changes in problem-solving behavior, but no evidence to support the assertion that concept development results from inquiry training. Furthermore, the data showed no relationship between the factors of intelligence, age, sex, and factual knowledge and changes in problem-solving behavior.

In the study done by Raven in 1965 (Williams & Herman, 1971, pp. 79-80), one hundred sixty children in kindergarten through grade three were asked to solve a problem for each of six concepts: conservation of matter, speed, proportional use of matter with momentum held constant, proportional use of speed with momentum held constant, and two momentum tasks. The findings showed that the younger children had more difficulty with the tasks than the older children. From these findings he concluded that the developmental stages of logical thought processes of children [Piaget] is more adequate in determining curriculum sequence than the logical, content sequence approach [Gagné]. However, Weaver and Coleman's study in 1960 (Williams & Herman, 1971, p. 80) showed that even slightly below average first grade children can develop science concepts when taught by a developmental sequence curriculum using a problem-solving approach.

After the study by Joyce and his associates (1966) in which it was indicated that children's attempts to explain observations of
simple scientific demonstrations were generally inadequate, incorrect or inappropriate, they warned that new programs in elementary school science should be certain of the conceptual levels to which pupils do and do not respond. Developers of new programs should be sure that children develop the major ideas in a progressive pattern, level-by-level, in order to lead to real understanding. Dunfee (1967) points out that this same warning is echoed in studies by Kerns in 1964 in which he stresses the importance of curriculum planning which provides for a pattern of progressive conceptual development; by Harris and Ulrich in 1964 concerning kinetic-molecular heat and kinetic-molecular motion in which they concluded that grade placement of such content is not profitable below grade six; Bailey in 1941, Hill in 1961, McCollum in 1952, and Oxendine in 1953 generally found that correct understanding of science knowledge, principles, and phenomena comes with increasing maturity.

On the other hand, there are those who have investigated the same question of content placement and have concluded that the thinking and understandings of children can be quite mature when given meaningful experiences. Studies by Anderson in 1965, Haupt in 1948 and 1952, Navarra in 1955, McNeil and Keislar and Yuckenberg in 1962 support this theory (Dunfee, 1967).

Barker (1965) tested the idea that pupils exposed to a discovery table which they were encouraged to use in experimenting as much as they wished would learn a great deal of scientific information on their own. His studies of one hundred sixty-four children, ages ten and eleven, produced evidence to support his hypothesis. On the other
hand, Butts (1963) concluded, after confronting intermediate grade pupils with a science phenomenon and giving them freedom to do with the experience as they wished, that while self-discovery is rewarding and motivating, it must depend upon some external direction which focuses attention on the relationships involved. Butts questioned the adequacy of independent manipulation of data as being sufficient for concept development.

Carpenter (1963) tested textbook recitation versus problem-solving methods in teaching science to fourth grade pupils in a situation in which roles were reversed during the study. He found that the results consistently favored the problem-solving approach to instruction. Bennett's (1965) comparison of the experimental-fields method and the traditional classroom method involving content in ecology for the seventh grade, led to the conclusion that neither approach had an advantage in producing science learning.

Numerous studies through the AAAS Competency Measures (1970) have been conducted concerning process skill development of students taught through a process approach which clearly indicate that students do learn process skills. Again, this was borne out in Partin's (1967) study and also in a study conducted in the Lakewood (Ohio) Public Schools (1971) for the American Association for the Advancement of Science. However, the main conclusion of the Lakewood study was that students taught by the process curriculum, Science - A Process Approach, did not score significantly higher on a test of science processes than the control group instructed through the more content-oriented approach of the Lakewood curriculum.
According to Dunfee (1967), even though the results of the studies are not consistent concerning children's development of science concepts, there is a certain recurrence in the findings. It appears that concept development is not simply a matter of acquiring information nor of attaining a certain age level, grade level, or maturity level. The essential characteristics seem to be the experiences a student has in concept development and the direct focus of instruction upon concept development.

Children's Science Interest

The science interests of children have not appeared to be of the greatest concern in recent curriculum developments (Dunfee, 1967), but it is related to this study because most of the investigations include a sex/interest relationship which is a factor in the hypotheses developed. Further, students' interest in science and motivational factors which evolve are indirectly related to the differences between process and content curriculum.

Perrodin (1966) worked with five hundred fifty-four children in grades four, six, and eight in an effort to determine their interests, whether these interests correspond to the program, and whether or not interests change as pupils move through the elementary school. Through a technique of open-ended sentences, Perrodin found that in an era of space exploration, children's interests were in health, safety, and the human body. The study of living things was popular, particularly for girls. Little interest was shown in the physical sciences, with boys' interests exceeding girls'. Bowen (1964) examined the science inter-
ests of boys and girls through a science fair activity. Of twenty-two projects on display, the physical sciences were overwhelmingly chosen by boys and the biological sciences by girls. The findings of Bowen and Perrodin are in contrast to earlier studies by Fitzpatrick in 1937 (Dunfee, 1967) who found no marked preferences for biological or physical sciences by boys or girls.

Whether elementary children like or dislike the study of science in school has been done by others. The classic study by Jersild and Tasch in 1949 (Dunfee, 1967) showed that children did not mention either favorably or unfavorably the study of science. Greenblatt (1962) also found science in a middle position of popularity with art, reading, and arithmetic being more popular. However, in the Greenblatt study, sex differences were evident with boys showing a preference for science, girls for music. The findings of Jersild and Tasch and Greenblatt are in contrast to other studies by Baker and Drill in 1945, Hardin in 1965, Johns in 1964, Morton and Smith in 1954, and Young in 1957 (Dunfee, 1967) who found wide, general scientific interests by students whether male or female. According to Kuslan and Stone (1968, p. 70), one example in Blanc's review of science interest studies in 1958 showed that in the analysis of free discussion periods children talked most often about nature and science. Of all sharing topics analyzed, 25.9 per cent included such topics as plants, animals (pets), space, astronomy, geology, weather, chemistry, and energy.

A study reported by Dunfee (1967, p. 20) is quite appropriate for the era in which this investigation was made—the particular societal issue being sex discrimination or sex stereotyping. In 1966,
Gaetano studied elementary science textbooks from six publishers to determine from the illustrations the distribution of males and females. In the primary textbooks, she found no significant difference between the distribution of the sexes. However, in 16 of the 18 intermediate books, males were more prevalent to a significant degree. Gaetano raised the question of the possible effect of the predominate use of male figures in illustrations on girls' choice of science as a career.

Most of the interest studies in elementary science confirm the deep interest of children in science. As pointed out by Kuslan and Stone (1968), interest is a strong motivation for the student. However, in school the child who was relatively autonomous before entering school is under pressure to be interested in teacher-originated tasks, and his interests are quickly dissipated. It is important, therefore, that a rich classroom experience is provided through which potential interest is transformed into actual interest. Because of the close relationship of interest to motivation and achievement, it is important to continue to determine those aspects of science which stimulate pupil interest as a major effort in elementary science education (Dunfee, 1967).

**Assessing Newer Approaches in Elementary Science**

According to Dunfee (1967), science educators will continue to assess the value of new science approaches by comparison with more established practices. She points out that in 1966 Brownell wrote of the necessity for viewing results of comparison studies made between newer approaches in science instruction and more established practices
most cautiously, for these reasons:

1. In such studies it is possible to sample only a part of the possible content. With other content, results might be different.

2. It is unlikely that exactly the same content will be taught to all groups being compared, even within groups supposedly following the same program.

3. The influence of objectives upon the desirability of a particular program cannot be overlooked. For one objective, one approach may be best; for a different objective, another program may be more appropriate.

4. There is a strong likelihood that pacing of instruction may necessarily differ in the programs used, with the consequence that children pursuing unlike programs may be "caught" at different points in the attainment of given objectives.

5. The prescribed plan very possibly cannot be implemented by all teachers equally well.

6. The quality of teaching in comparison studies is extremely difficult to control (p. 39).

Brownell believes that the extent to which these variables can be controlled will determine the significance of results derived from studies in which varying approaches are compared for their effectiveness in reaching certain objectives.

Whether or not evidence will be found to prove that one science curricular approach is superior to another, there seems to be growing support for the idea that a wide variety of direct experiences improve children's concept development, interests, and scientific behavior.

Nevertheless, there is little specific research, particularly for those using a process method such as Science - A Process Approach, which shows that the students do learn science knowledge. Kuslan and Stone (1968) support this premise as follows:

Unfortunately, there is no large body of experimental evidence which testifies to the effectiveness of Inquiry in leading children to a more coherent and deeper knowledge of science content, principles and theories. The limited research in Inquiry only hints, rather than proves, that this kind of learning is facilitated (p. 97).
Ausubel and Robinson (1969), too, support this notion that little specific research, espousing the merits of a process approach, is available in their following statement:

Despite their frequent espousal of discovery principles, the various curriculum reform projects have failed thus far to yield any research evidence in support of the discovery method. This is not to say that the evidence is negative, but rather that there just is not any evidence one way or the other. One reason for the lack of evidence is that the sponsors of some of these projects have not been particularly concerned about proving the superior efficacy of their programs, since they have been thoroughly convinced of this from the outset. Hence in many instances they have not even attempted to obtain comparable achievement test data from matched control groups. And only rarely has any effort been expended to prevent the operation of the crucial "Hawthorne Effect," that is, to make sure that evidence of superior achievement outcomes is attributable to the influence of the new pedagogical techniques or materials in question rather than to the fact that the experimental group is the recipient of some form of conspicuous special attention, that something new and interesting is being tried, or that the teachers involved are especially competent, dedicated, and enthusiastic—and receive special training, attend expense-free conventions and summer institutes, and are assigned lighter teaching loads (pp. 494-495).

Therefore, the problem becomes one of measuring the science knowledge achievement of process-taught students as compared to content taught students to determine whether children taught by a science process approach achieve science knowledge comparable to children taught by a content approach.

Summary

The review of current literature presents a historical development of elementary school science in an attempt to show the stages of change in the field in a sequential order. Through this development there is a sequence leading to the recent trends and issues in elementary science which focus on the main aspects of the present study, the
comparison of a process or content approach to the study of science in the elementary school.

Basically, before 1950 elementary science was primarily nature study. In its early stages, science in the elementary school held three goals: (1) theological, (2) utilitarian, (3) disciplinary. By the 1850's, the object lesson method of science instruction became quite acceptable even though memorized recitations from textbooks was the overwhelmingly accepted method. Science education was given impetus through the late 1800's by Spencer's essay What Knowledge Is of Most Worth and the N.E.A.'s Committee of Ten and Committee of Fifteen. These writings gave importance and status to science subjects and influenced new developments in science teaching, training, and curriculum development. Around the turn of the century the nature study movement became the educational fad replacing object lessons. Comstock's book, Handbook of Nature Study, was most influential during that period. By the 1920's, nature study began to wane and the science field was influenced by Dewey's contention that methodology of science was of equal or greater value than the actual knowledge. Craig's work at Columbia's Horace Mann Elementary School had the greatest impact for he saw the importance of systematically organizing the science areas around the major concepts. The writings of the Thirty-first Yearbook were also quite influential in establishing elementary school science in the curriculum of the schools. The end of World War II found the beginning of the educational reform period in which there was a negative reaction to the still predominate social utility/nature study approaches stressed in science education during the thirties and
forties. Scientists themselves turned to correcting the deficiencies they found in the field such as the lack of knowledge of the area of science as understood by scientists, the lack of organization, and the lack of exposure to experimentation. From this reform period came the thrust for inquiry, process development and the active involvement of the children in science learning. New programs were developed in the sixties with two major strands of purpose emerging—process-goals and product-goals. By the late sixties and into the early seventies, a new trend began to emerge: to teach by performance objectives. By developing carefully sequenced educational materials designed to enable each child to move at his own pace, it was the hope of educators that children, regardless of race or economic background, would be able to achieve their potential [to develop basic concepts and skills of science].

The research selected for review supports the literature as the two main goals of the reform period emerged—process- and product-goals. Of the many strands of science education research available, concept development and children's interest in science were those most related to the present investigation.

Studies concerning, if, and/or, how well children develop science concepts or achieve scientific knowledge are not too consistent. However, there is a recurrence in the findings which indicate that concept development is more than acquiring information or attaining a certain maturation level. The essential factors seem to rest on the experiences the student has had in concept development and whether or not the instruction focused on concept development.
Most of the interest studies in elementary science confirm the deep interest children have for science. Because of the close relationship of interest to motivation and achievement, it is important that those developing newer programs in the field continue to give attention to those aspects of science which stimulate pupil interest.

The amount of literature and research in elementary science is evidence of the lively interest in the field. According to Dunfee (1967), the amount and kind of research are quite in contrast with that of fifteen to twenty years ago when very few aspects of elementary science had been explored systematically in any depth. Today, curriculum research and literature in the field of elementary science education is relatively extensive; objectives are being redefined and clarified; children's learning is being more carefully examined; new materials are being designed and tested; methods of instruction are being emphasized and compared with more conventional approaches; and research will continue and even accelerate.

As cited by Washton (Dunfee, 1967), primary concern should be on research in the teaching of science for creativity. He identifies several needs that merit consideration: (1) to determine when certain types of pupil questions lead to creativity; (2) to identify by some standard measure those students who are creative, not merely intelligent; (3) to study the ability of pupils to raise significant problems for study; (4) to find out how pupils can be led to experiment and to accept or reject hypotheses they have formulated; and (5) to study the relationship of teacher creativity and flexibility to creativity in children.
CHAPTER III

Methods and Procedures

Subjects

The subjects for the study came from the Lakewood (Ohio) City School District. Lakewood is a white, first-ring suburban community bordering on Cleveland's (Ohio) western boundary. It is a residential or bedroom community of about 73,000 residents made up of about sixteen per cent professional workers with the remainder of the working population engaged in skilled, clerical, semi-professional, and semi-skilled occupations. Lakewood was once regarded as a wealthy or high middle-income city but is now considered a middle to low-middle income community.

Lakewood's closeness to Cleveland (the closest suburb to downtown Cleveland) has made it an attractive residential community for Cleveland workers. There are about 29,000 family dwellings made up of about one-third single family dwellings, one-third double family units, and one-third apartments. Most of the housing was built during Lakewood's period of rapid growth, the 1920's, so the housing is generally older but usually well maintained and attractive. Because of its limited physical size and large population, Lakewood is one of the more densely populated communities in the country, with approximately 13,000 persons per square mile compared with Cleveland's approximate 9,000. About two-thirds of the dwelling units are rental properties, a condition which promotes a certain transiency population
not found in more self-contained communities.

Lakewood's residents can be roughly divided into one-half Catholic and one-half Protestant. About one-third of the school age population attend parochial or private schools; however, this figure is beginning to show a decline in deference to the public schools. The enrollment of the public schools has been rather constant with some increases due mainly to the transferring of private students.

The citizens of Lakewood have always held their educational system in high esteem. Even with newer people moving into the community, the "mystique" of the Lakewood Schools has been maintained. Excellence in education has always been a requirement of Lakewood families since the citizenry has a very high level of educational attainment. In a recent community census, 12.2 per cent of the new residents interviewed stated they were attracted to the community because of the reputation of the Lakewood Schools.

The Lakewood Schools have remained in the forefront of educational innovation. Individualized instructional programs, open area concept schools, team teaching, non-gradedness, the school-within-a-school concept at the state's largest high school, preschool education, volunteer aide programs, and comprehensive programming including extensive vocational offerings, are all characteristic of the Lakewood Schools today.

Lakewood has ten elementary schools with a K-5 student population of about forty-seven hundred. Subjects used in this study were randomly selected from eight of the ten schools which were comparably matched by the method used in science instruction, the socio-economic
nature of the population and the intelligence and achievement records of its student population. A summary of these comparable characteristics between the two groups of school populations is reported in Table 1.

### Table 1

Summary of Comparable Characteristics of the Two Groups of Test School Populations

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Process Approach School Populations</th>
<th>Content Approach School Populations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Years of Process or Content Approach Instruction</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Mean I.Q. on California Test of Mental Maturity, Grade 4</td>
<td>108.25</td>
<td>108.25</td>
</tr>
<tr>
<td>Mean Grade-equivalent Composite Score on Iowa Test of Basic Skills, Grade 4</td>
<td>4.975</td>
<td>4.975</td>
</tr>
<tr>
<td>Mean Number of ADC Children, 1972</td>
<td>35.75</td>
<td>29.75</td>
</tr>
</tbody>
</table>

Essentially, a three-stage, stratified, random sampling procedure was employed to select subjects for each type of instructional group. First, all students who had received five consecutive years of science instruction by either the process approach or the content approach were identified. Second, from the above samples for each instructional group, students of high intelligence (115 I.Q. and above) and students of low intelligence (99 I.Q. and below) were selected. Third, from these two groups of high and low intelligence, sixty stu-
dents each were randomly selected to represent the process instructional group or the content instructional group. Of the sixty students randomly selected for each group, fifteen boys and fifteen girls were selected for each of the four groupings required as appears in Table 2.

**TABLE 2**

Random Selections for Data Matrix

<table>
<thead>
<tr>
<th>Instructional Treatment</th>
<th>High I.Q.</th>
<th>Low I.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process Instructional</td>
<td>N = 15</td>
<td>N = 15</td>
</tr>
<tr>
<td>Approach</td>
<td>N = 15</td>
<td>N = 15</td>
</tr>
<tr>
<td>Content Instructional</td>
<td>N = 15</td>
<td>N = 15</td>
</tr>
<tr>
<td>Approach</td>
<td>N = 15</td>
<td>N = 15</td>
</tr>
</tbody>
</table>

**Procedures**

**The Process Approach**

Since 1967 children in four Lakewood (Ohio) Public Elementary Schools—Grant, Harrison, McKinley, and Roosevelt—have been instructed in science through a process approach, *Science - A Process Approach*. The American Association for the Advancement of Science developed this program which emphasizes the processes of science in its curriculum design. Authors of this program say, "...It is no mean pedagogical feat to teach a child the facts of science and technology; it is a pedagogical triumph to teach him these facts in their relation to the procedures of scientific enquiry (AAAS, 1970, p. 3)." "Science - A Process Approach makes the assumption that science is more than an encyclopedic collection of facts, and that children, even in the
primary grades, will derive more from the study of science if they learn the behaviors of the scientists (AAAS, 1970, p. 9)." It assumes that science is what scientists do.

As participants in the process methodology, the students were taught, from the primary levels through the intermediate grades, to use the following selected processes of science (AAAS, 1970, p. 10):

**Basic Process Skills - Primary Grades**

- Observing
- Measuring
- Using Space/Time Relationships
- Communicating
- Classifying
- Predicting
- Using Numbers
- Inferring

**Integrated Process Skills - Intermediate Grades**

- Controlling Variables
- Defining Operationally
- Interpreting Data
- Experimenting
- Formulating Hypotheses

These students were helped to acquire and practice these processes of science as intellectual skills in a manner that would aid them in their future learning in science as well as in other areas.

As stated by the authors (AAAS, 1970):

> The procedures of scientific enquiry, learned not as a canon of rules but as ways of finding answers, can be applied without limit. The well-taught child will approach human behavior and social structure and the claims of authority with the same spirit of alert skepticism that he adopts toward scientific theories. It is here that the future citizen who will not become a scientist will learn that science is not memory or magic but rather a disciplined form of human curiosity (p. 4).

Students learned the process skills in a hierarchical manner, later learning building upon earlier learning. The processes were
practiced again and again over the years in the spiraling manner ad-
vocated by Jerome Bruner (1963) assuming more breadth and depth as the
child became more mature. As the processes were developed, new content
areas were used to develop the ability to transfer the skills or pro-
cess procedures to new problem situations.

Success did not depend on skill in reading or acquiring a
mass of facts but, rather, on the student's ability to use the processes
of science. According to the authors (AAAS, 1970):

Most of the materials have been prepared for the teacher
only. Rather than reading about science, in this curriculum,
children learn science through the use of their senses, mental
involvement, and direct manipulation of objects in their im-
mediate environment. Of course, some children want to know
more about topics they investigate. Reading about science and
scientists is an important supplement to a child's investiga-
tions (p. 10).

Although the authors of Science - A Process Approach give great
emphasis to the processes of science, they admit that "...you cannot
teach scientific processes without using some content" (AAAS, 1970,
p. 11). They say that:

Much science content is included in Science - A Process Ap-
proach, but the emphasis is on the processes. In order to
attain competence in the processes of science, children deal
with such topics as plants, animals, energy, light, tempera-
ture, heat solids, liquids, gases, life cycles, electricity, magne-
tic fields, motion, and many others. The children become
very interested in and curious about the topic they are study-
ing even though the primary objective of the instruction is
for them to acquire new competencies in the processes of
science (p. 11).

The teachers who taught Science - A Process Approach did have
to undergo a certain amount of in-service training in order to acquaint
them with the program, the procedures and materials. As stated in the
Commentary for Teachers (AAAS, 1970, p. 14), "...The greatest diffi-
The Content Approach

Since the early sixties, Lakewood (Ohio) Public Elementary School children have been learning science through a content approach as prescribed and published by the school system (Science: Grade One; Science: Grade Two; etc.) with the exception of those children taught by a process approach since 1967. Four Lakewood Elementary Schools—Garfield, Hayes, Lincoln, and Madison—have continued to use this content approach to science learning since that time. The Lakewood program emphasizes content learning or the acquisition and understanding of scientific knowledge and the fundamental principles of science. Proponents of this approach to science learning generally agree with Ausubel’s (1966–67) position as follows:

In my opinion, any science curriculum worthy of the name must be concerned with the systematic presentation of an organized body of knowledge as an explicit end in itself. Even if it is relatively superficial and organized on an intuitive basis, as it must be in the elementary school, the science curriculum should make a start in this direction and give the student a feeling for science as a selectively and sequentially organized structure of knowledge (p. 3).

The content approach assumes that children learn scientific knowledge as described by Blackwood (1964):

The scientific knowledge which children learn may appear in different forms—as generalizations, principles, facts, conclusions, laws. Year by year children develop a more comprehensive set of concepts which they use as intellectual tools in interpreting and understanding new phenomena or problems. Keeping the focus on concept development enables curriculum planners and the teacher, in particular, to make judicious se-
lection of the aspects of the environment to study so that there is not a compulsion to try to cover all aspects of our universe each year, or indeed year after year (p. 24).

As participants in the content approach methodology, the students were taught science from the primary levels through the intermediate grades, through a comprehensive and sequentially organized program centered around a topical framework of recognized science fields (Lakewood, 1971) as shown in Figures 1-3.

Under each of these topical headings there are controlling concepts from which numerous instructional concepts were developed, such as: Grade 5, controlling concept, Living Things Help and Harm Each Other, instructional concept, Some Animals Are Harmful and Should Be Controlled; Grade 3, controlling concept, Using Electricity, instructional concept, Electricity Will Flow Only in a Complete Circuit; A Break in the Circuit Stops the Flow of Electricity. Through this method of concept development "...the study of science should help boys and girls come to know some generalizations or big meanings or science principles that they can use in solving problems in their environment (Blough, Schwartz, & Huggett, 1958, p. 12)."

Admittedly, the Lakewood program is much more inquiry-oriented than the typical content approach, usually thought of as the textbook method. As stated by Carpenter (1963, p. 256), "The 'Textbook-Recitation Method' simply means treating science more or less as an extension of the reading program; teaching the material by reading and discussing a basic textbook, and requiring the pupils to answer the questions found in the textbook." Also, the Lakewood program is unlike another method of content development "...a body of knowledge to be
## FIGURE 1

### Living Things, Plants and Animals

<table>
<thead>
<tr>
<th>Grade</th>
<th>Plants</th>
<th>Animals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kindergarten</td>
<td>Plants</td>
<td>Kinds of Animals</td>
</tr>
<tr>
<td></td>
<td>Care of the Farm</td>
<td>Pets</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Building an Aquarium</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Young Animals</td>
</tr>
<tr>
<td>First Grade</td>
<td>How Plants Grow</td>
<td>Animals' Homes</td>
</tr>
<tr>
<td></td>
<td>Seeds</td>
<td></td>
</tr>
<tr>
<td>Second Grade</td>
<td>Seasonal Changes: Fall</td>
<td>Under-water Life</td>
</tr>
<tr>
<td></td>
<td>Seasonal Changes: Spring</td>
<td>Animal Development</td>
</tr>
<tr>
<td>Third Grade</td>
<td></td>
<td>Animals Are Different</td>
</tr>
<tr>
<td></td>
<td>Plants and Animals of the Cleveland Region</td>
<td></td>
</tr>
<tr>
<td>Fourth Grade</td>
<td>How Plants Grow</td>
<td>Groups of Animals</td>
</tr>
<tr>
<td></td>
<td>(Gardening)</td>
<td></td>
</tr>
<tr>
<td>Fifth Grade</td>
<td>Living Things Help and Harm Each Other</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plants and Animals Then and Now</td>
<td></td>
</tr>
<tr>
<td>Sixth Grade</td>
<td>Energy and Plant Growth</td>
<td>Animals and Seasonal Change</td>
</tr>
<tr>
<td></td>
<td>Plant and Animal Communities</td>
<td></td>
</tr>
</tbody>
</table>
FIGURE 2
Non-Living Things: The Earth and the Universe

<table>
<thead>
<tr>
<th>Grade</th>
<th>Conservation</th>
<th>Earth</th>
<th>Air, Weather</th>
<th>Universe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kindergarten</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First Grade</td>
<td>The Soil</td>
<td>Rocks Near You</td>
<td>Weather</td>
<td>Seasons</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sun and Shadows</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Day &amp; Night</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second Grade</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Third Grade</td>
<td>Wind &amp; Water</td>
<td>Dinosaurs</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Change the Earth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fourth Grade</td>
<td>Waters of the Earth</td>
<td>The Earth</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>The Seasons</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Waters of the Earth</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Studying Rocks and Minerals</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conservation of Minerals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fifth Grade</td>
<td></td>
<td>Balance</td>
<td>Weather</td>
<td>The Solar System</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shape &amp; Motion</td>
<td>Today &amp; Tomorrow</td>
<td></td>
</tr>
<tr>
<td>Sixth Grade</td>
<td>Using Water, Soils and</td>
<td>Why the Seasons</td>
<td></td>
<td>The Milky Way and Beyond</td>
</tr>
<tr>
<td></td>
<td>Forests Wisely</td>
<td>Change</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## FIGURE 3
Non-Living Things, Matter and Energy

<table>
<thead>
<tr>
<th>Grade</th>
<th>Magnetism &amp; Electricity</th>
<th>Phys. &amp; Chem. Properties and Changes</th>
<th>Sound Light &amp; Heat</th>
<th>Energy &amp; Machines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kindergarten</td>
<td></td>
<td>Feel and Find Out</td>
<td>Sound</td>
<td>Toys</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sorting &amp; Grouping Materials</td>
<td></td>
<td>The Inclined Plane</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Wind and Water Move Things</td>
</tr>
<tr>
<td>First Grade</td>
<td>Magnets</td>
<td>Things That Float in Air and Water Water &amp; Its Properties</td>
<td>Light</td>
<td>Simple Machines</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Gravity &amp; Balance</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Measuring &amp; Weighing</td>
</tr>
<tr>
<td>Second Grade</td>
<td></td>
<td>Testing Properties of Matter</td>
<td>Sounds Around You</td>
<td>Making Things Move</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Friction Airplanes</td>
</tr>
<tr>
<td>Third Grade</td>
<td>Magnets &amp; Compasses Using Electricity</td>
<td>Changes All About You</td>
<td>Space Travel</td>
<td></td>
</tr>
<tr>
<td>Fourth Grade</td>
<td></td>
<td></td>
<td>Sound</td>
<td></td>
</tr>
<tr>
<td>Fifth Grade</td>
<td>Electricity</td>
<td>Chemicals Everywhere Balance Shape, Motion</td>
<td>Heat Causes Changes</td>
<td></td>
</tr>
<tr>
<td>Sixth Grade</td>
<td>Matter and Energy</td>
<td>Light Energy</td>
<td>Matter &amp; Energy Machines to Direct Energy Earth's Air-ways &amp; Beyond</td>
<td></td>
</tr>
</tbody>
</table>
crammed into the heads of the students (Sund & Trowbridge, 1967, p. 39)." In fact, the Lakewood program (1968) defines its goals as follows:

- to know some fundamental principles of science
- to learn something of the processes of science
- to understand the investigative nature of science
- to appreciate some of the attitudes inherent in the scientific process (p. i)

The philosophy of the Lakewood (1968) program concludes with this statement:

So a good science program is directed not only toward developing an ever-increasing understanding of large concepts concerning the universe but also toward developing a love of investigating and learning which will continue throughout life (p. ii).

The content approach of the Lakewood program is more an activity-oriented method using discovery procedures rather than textbook procedures. The Lakewood guide (1968) states:

The book, then, is a tool, not a master. The books are used as the need arises for factual information. Pupils should be encouraged to consult a wide variety of resource materials. Trade books are provided in areas where factual information would seem to be needed most (p. ii).

In the Lakewood program, the teachers are expected to follow the curriculum guide for their grade level (Science: Grade 1; Science: Grade 2; etc.). This is the backbone of the program which determines the content of the units to be taught and the procedures for instruction. Books are provided for every science classroom but reading matter is not supplied for every unit to be taught. Only reading matter is used for those units where reading matter is required as the most effective method of instruction. Some of the basic reading materials include:
Grade 2 - Today's Basic Science, Book 2

Grade 3 - Earth Satellites

   The Moon
   The Sun
   The Earth Around Us
   Dinosaurs

Grade 4 - The Earth's Crust

   The Sun, Seasons and Climate
   Oceans
   What's Inside of Plants

Grade 5 - Materials of the Earth

   Changes in Matter
   Exploring the Solar System
   Distances in Space
   The Milky Way and the Universe
   The Wind
   What Is Heat
   Electricity
   Insect and Senses
   Prehistoric Plants and Animals

It appears that the goals of the Lakewood program are similar to the goals of the AAAS program; it is the method and content emphasis which seems different. While Science - A Process Approach employs certain science content as a vehicle by which to teach scientific processes, the Lakewood program uses the processes as the vehicle for teaching science content. Both methods emphasize concepts or principles
rather than isolated facts.

The teachers who taught the Lakewood program were given periodical sessions of in-service education in order to up-date their knowledge and skill, to clarify instructional procedures, and to review program content and material and equipment usage. The amount of in-service education for teachers of the Lakewood program did not fully equal the amount of in-service training required of AAAS teachers due to the fact that Lakewood program teachers were teaching a program familiar to them which only required their periodic up-dating. AAAS teachers were teaching a new and sometimes changing program [revised twice during the five years covered in this study] which required acquaintance, familiarity, new skill and knowledge. Obviously, the in-service work for AAAS teachers was somewhat more extensive but there was not so much difference as to establish an unbalance or "halo effect" favoring AAAS.

**Measurement Instruments**

In order to assist in the randomized selection of students, the total I.Q. scores derived from the California Test of Mental Maturity, annually administered to fourth grade students in the Lakewood Schools, were used. This test, the 1963 edition of S-Form - Level 2, was administered in October, 1971 to seven hundred seven fourth grade pupils. The CTMM is used in the Lakewood Schools because it "...is an effective diagnostic test since it provides a language, non-language, and total I.Q. score (Lakewood, 1971-72, p. 122)." Stanley states in his evaluation (Buros, 1965):
Overall, the reviewer feels that the CTMM S-Form is most useful at kindergarten through about the third (Levels 0 and 1) and progressively less useful in the higher grades. Its emphasis on nonverbal material, perhaps appropriate for children learning to read, is disproportionate at the higher levels (p. 696).

As pointed out by the California Test Bureau (1964):

The Total I.Q. ranks an individual in overall mental maturity in relation to others of the same chronological age and has value as a single score in predicting how well a student will do in school.... The results of many studies demonstrate that there is strong relationship between Total I.Q. and performance on achievement tests (p. 7).

During the eighth month (April) of the students' fifth year of learning science through the AAAS process approach or the Lakewood content approach, those students randomly selected to participate in the study were given an achievement test in science. The testing instrument used was the Sequential Test of Educational Progress: Science (STEP), Series II, Form 4A, 1969. The STEP test in science is one of the series of achievement tests published by the Educational Testing Service. It is a fifty question, objective, standardized test of science understanding. The series also includes sub-tests in English expression, reading, mechanics of writing, mathematics computation, mathematics basic concepts, and social science.

Flanagan (Buros, 1965), one of the test reviewers of the 1957 edition, said that the commendable purposes of the science test, to measure scientific processes, were not satisfied because the STEP has the same deficiencies as other standardized tests: it best measures the knowledge of facts.

The technical handbook of the STEP, Series II (Educational Testing Service, 1971) states:
The Science tests measure knowledge and understanding of the fundamental concepts and processes of science, the comprehension and application of this knowledge, and the mastery of science skills. Major emphasis is placed on biology [fifty per cent of the questions are in this area]; physics and chemistry receive modern emphasis [thirty-two per cent of the questions are in these areas]; and the earth sciences, including astronomy, geology, and meteorology, receive the least emphasis [eighteen per cent of the questions are in this area] (p. 101).

The technical handbook goes on to define the classification of the science items as follows:

**SCIENCE ITEM CLASSIFICATION CATEGORIES**

**Skill**

Knowledge, the ability to recall ideas, material, or phenomena. Comprehension, the ability to translate ideas or material from one method of expression to another; to interpret material presented or to extrapolate from it. Application, the ability to use learned information in answering an unfamiliar question or solving a new problem. Higher level skills, analysis, the ability to break down material into its constituent parts and to detect the relationships among them and the way they are organized; synthesis, the ability to combine parts to produce a new pattern or structure; evaluation, the ability to make purposeful judgments of ideas and solutions.

**Content**

Biology, includes development, ecology, evolution, heredity, morphology, physiology, and taxonomy. Chemistry, includes atomic structure and bonding, kinetic-molecular theory, the chemistry of particular substances, energy considerations, and fundamental terms and calculations. Some questions are laboratory oriented. Physics, includes atomic and nuclear physics, electricity and magnetism, heat and kinetic theory, mechanics, optics, and waves. Earth Sciences, includes astronomy, geology, and meteorology (p. 101).

This test was selected from a number of other science achievement tests because a review of current test instruments and a study of evaluation remarks by test evaluators compiled in The Sixth Mental
Measurements Yearbook (Buros, 1965) indicated the STEP test in science was the most valid and reliable instrument for the purpose of this study. Although both Mallinson and Flanagan (Buros, 1965) have pointed out deficiencies in their evaluations of the STEP test in science, they both indicated that no better elementary science test is available. In fact, Mallinson says:

Since there is a dearth of suitable evaluation devices for science, ...the STEP tests may probably be considered the best of a poor lot. Their use is recommended because of a lack of other suitable tests (p. 1162).

Statistical Design of the Study

The statistical design of the study was a 2 x 2 x 2 hierarchical analysis of variance where two levels of treatment constituted the principal variable and subjects were nested by sex within the levels of the treatment variable. In addition, subjects were blocked by intelligence scores. The data matrix for the design appears in Table 2.

The variables were as follows:

Variable A (Intelligence)

Level I - Classification variable. Intelligence quotient as measured by the California Test of Mental Maturity. This block will include quotients from 115 and above. This range will be referred to as the high level.

Level II - Classification variable. Intelligence quotient as measured by the California Test of Mental Maturity. This block will include quotients from 99 and below. This range
will be referred to as the low level.

**Variable B (Treatment)**

**Level I** - Manipulated variable where content is controlled. Process approach is used.

**Level II** - Manipulated variable where content is controlled. Content approach is used.

**Variable C (Sex)**

**Level I** - Nested variable. Sex, male.

**Level II** - Nested variable. Sex, female.

**Dependent Variable (Test Instrument)**

The dependent variable will consist of a fifty question, objective, standardized test of science understanding known as *Sequential Tests of Educational Progress: Science (STEP)*. This is a test instrument developed and published by Cooperative Test Division, Educational Testing Service, Princeton, New Jersey.

Such an analysis permitted the assessment of the stated hypotheses as follows:

**Hypothesis one** - there will be no differences in the achievement of fifth grade students in science knowledge as measured by the STEP test in science between the groups instructed through a process-oriented approach and the groups instructed through a content-oriented approach—was tested by analyzing the differences between the two levels of the treatment variable.
Hypothesis two - there will be no differences in the achievement of fifth grade boys in science knowledge as measured by STEP between process-taught boys and content-taught boys—was tested by analyzing the differences among levels of the sex variable (boys).

Hypothesis three - there will be no differences in the achievement of fifth grade girls in science knowledge as measured by STEP between process-taught girls and content-taught girls—was tested by analyzing the differences among levels of the sex variable (girls).

Hypothesis four - there will be no differences in the achievement of process-taught fifth grade boys in science knowledge as measured by STEP and process-taught girls—was tested by analyzing the differences among the levels of the sex variable.

Hypothesis five - there will be no differences in the achievement of science knowledge by low-intelligence, process-taught fifth grade students as measured by STEP and low-intelligence, content-taught students—was tested by analyzing the interactions of the two levels of treatment and the sex and intelligence variables.

Hypothesis six - there will be no differences in the achievement of science knowledge by high-intelligence, process-taught fifth grade students, as measured by STEP and high-intelligence, content-taught students—was tested by analyzing the interactions of the two levels of treatment and the sex and intelligence variables.
Summary

The major purpose of this study was to investigate the achievement of science knowledge as acquired by fifth grade students after five years of instruction in science through either a process approach or a content approach. Sixty students were randomly selected from the group of four elementary schools teaching science by the process approach and from the group of four schools teaching science by the content approach. Each group of sixty students was selected by sex, intelligence and five years of instruction in one or the other curricular approach in order to establish four cells of fifteen students each for the data matrix; fifteen boys and fifteen girls of high-intelligence were selected for each approach and the same distribution of boys and girls of low-intelligence were selected for each approach.

During the five year period, the teachers of both instructional groups received appropriate materials, in-service education, and supervisory assistance. However, the process approach teachers did receive somewhat more attention because their curricular approach was newly developed and completely unfamiliar to them. The major objective of utilizing two different curricular approaches was to determine what method best helped children of this age to achieve the necessary science knowledge to develop a degree of scientific literacy.

Data utilized for determining the achievement of science knowledge was gathered by the major instrument used in this study, the Sequential Test of Educational Progress: Science (STEP), Series
II, Form 4A, 1969. Supplementary information used for selection purposes was supplied by the California Test of Mental Maturity (CTMM), S-Form, Level 2, 1963.
CHAPTER IV

Analysis of the Data

Introduction

The Sequential Tests of Educational Progress: Science was admin­istered to fifth grade students to determine the effects of a process or a content instructional approach on the achievement of science knowledge. The science achievement test scores represented the dependent variable in the study. The achievement test scores were sub­jected to a 2 x 2 x 2 hierarchical analysis of variance where instruc­tional treatments, intelligence, and sex served as principal variables. The design employed for analysis enabled the researcher to compare and analyze the interaction of the three variables on the achievement of students. Also the use of intelligence and sex as variables provided a method of controlling for those variables which otherwise might have become confounding. All tests were electronically scored. All the com­putations of the analysis of variance were completed through the Monova Computer Program of Chi Corporation, Cleveland, Ohio.

The analysis of the data collected will be presented on the following pages. The means and standard deviations for all variables will be summarized. The results of the analysis of variance will be presented in a sequential manner beginning, first, with the analysis of interacting effects followed by the analysis of the main effects. A summary will be presented to briefly restate the analysis.
Means and Standard Deviations

The means and standard deviations of students' achievement on the Sequential Tests of Educational Progress: Science are presented by instructional treatment, intelligence, and sex in Table 3.

### TABLE 3

Means and Standard Deviations of Student Performance by Treatment, Intelligence, and Sex on the STEP Test

<table>
<thead>
<tr>
<th>Instructional Treatment</th>
<th>High Intelligence M</th>
<th>SD</th>
<th>Low Intelligence M</th>
<th>SD</th>
<th>Totals M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Process Approach</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>43.00</td>
<td>2.93</td>
<td>24.13</td>
<td>4.62</td>
<td>33.57</td>
<td>10.09</td>
</tr>
<tr>
<td>Girls</td>
<td>39.07</td>
<td>4.33</td>
<td>28.93</td>
<td>5.68</td>
<td>34.00</td>
<td>7.03</td>
</tr>
<tr>
<td>Sub Totals</td>
<td>41.03</td>
<td>4.08</td>
<td>26.53</td>
<td>5.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Content Approach</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>41.27</td>
<td>4.57</td>
<td>23.80</td>
<td>5.74</td>
<td>32.53</td>
<td>10.08</td>
</tr>
<tr>
<td>Girls</td>
<td>41.00</td>
<td>3.68</td>
<td>22.47</td>
<td>3.91</td>
<td>31.73</td>
<td>9.96</td>
</tr>
<tr>
<td>Sub Totals</td>
<td>41.13</td>
<td>4.01</td>
<td>23.13</td>
<td>4.81</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>41.08</td>
<td>4.04</td>
<td>24.83</td>
<td>5.40</td>
<td>32.95</td>
<td>9.85</td>
</tr>
</tbody>
</table>

Note. — All values rounded to the nearest hundredth.

A review of Table 3 shows the standard deviations for all cells being relatively close indicating a pre-equation of the samples. An example would be the difference between the standard deviations of the treatment groups (8.69 process; 10.03 content) which was 1.43.
An examination of the means presented in Table 3 shows that students taught with a process approach (33.78) did not appear to score markedly different from students instructed with a content approach (32.16) on a test of science knowledge. A large mean difference was achieved between the high-intelligence students (41.08) and the low-intelligence students (24.83); however, the main effects of the intelligence variable were not of interest in this study. It is a well accepted principle that there is a relatively close correlation between intelligence tests and other academic measures. In examining the means of the interaction of treatment and intelligence, it shows that the means for treatment changed over levels of intelligence. The means for high-intelligence students favored content-taught students (41.13) rather than process-taught students (41.03). However, when one studies the means for the low-intelligence students, it can be noted that the process-taught students (26.53) had a greater mean score than did the content-taught students (23.13). The means for the sex variable show that all content-taught boys (32.53) scored higher than all content-taught girls (31.73) whereas all process-taught girls (34.00) scored higher than all process-taught boys (33.57). Further, the mean for either process-taught boys (33.57) or process-taught girls (34.00) is greater than the mean for either content-taught boys (32.53) or content-taught girls (31.73). The differences in the means of the sex variable are not great and apparently not significant, which subsequently proved to be the case.

The mean scores presented in Table 3 were subjected to analysis of variance procedures to determine significance. A summary of the
analysis of variance results is found in Table 4.

**TABLE 4**

Analysis of Variance of Student Performance by Treatment, Intelligence, and Sex on the STEP Test

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>ss</th>
<th>ms</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>3</td>
<td>94.09</td>
<td>87.89</td>
<td></td>
</tr>
<tr>
<td>Process-Content Groups</td>
<td>1</td>
<td>81.68</td>
<td>81.68</td>
<td>3.98*</td>
</tr>
<tr>
<td>Sex/Process-Content</td>
<td>2</td>
<td>12.41</td>
<td>6.21</td>
<td>.30</td>
</tr>
<tr>
<td>Within Groups</td>
<td>116</td>
<td>10,602.70</td>
<td>8179.41</td>
<td></td>
</tr>
<tr>
<td>Intelligence</td>
<td>1</td>
<td>7921.87</td>
<td>7921.87</td>
<td>385.99*</td>
</tr>
<tr>
<td>Process-Content x Intelligence</td>
<td>1</td>
<td>91.88</td>
<td>91.88</td>
<td>4.48*</td>
</tr>
<tr>
<td>Intelligence x Sex/Process-</td>
<td>2</td>
<td>290.28</td>
<td>145.14</td>
<td>7.07*</td>
</tr>
<tr>
<td>Content</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>112</td>
<td>2298.67</td>
<td>20.52</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>119</td>
<td>10,696.79</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. — All values rounded to the nearest hundredth.

* P < .05

**Interaction of Intelligence and Sex**

Table 4 shows the F ratio for intelligence and sex to be significant (F = 7.07; df = 2/112; P < .01). The significant F ratio alerts the experimenter to the fact that significant differences exist somewhere among the means for sex and intelligence. To determine specific cell mean differences additional analysis is required. In Figure 4, the cell means for sex are plotted over intelligence to determine whether ordinal or disordinal interaction occurred.
FIGURE 4

Interaction of Intelligence and Sex

High I.Q.

Low I.Q.

μ = 32.95

Content Boys

Process Boys

Content Girls

Process Girls
Figure 4 illustrates what was noted earlier in the examination of the means. When blocking on intelligence, one would expect ordinal interaction. As an example, the boys' high-intelligence group should achieve higher than the boys' low-intelligence group in both process and content instruction. Figure 4 shows that process-taught girls changed positions relative to the other groups indicating that a disordinal interaction occurred. The process-taught, high-intelligence girls were the lowest group (39.07) when compared with the process-taught, high-intelligence boys (43.00), the content-taught, high-intelligence boys (41.27), and the content-taught, high-intelligence girls (41.00). However, the process-taught, low-intelligence girls (28.93) were the highest group when compared with the process-taught, low intelligence boys (24.13), the content-taught, low-intelligence boys (23.80), and the content-taught, low-intelligence girls (22.47). This would indicate that low-intelligence girls appear to learn more science knowledge when instructed by a process approach to science. The fact that disordinal rather than ordinal interaction occurred makes it impossible to speak to the value of the process or content approach for boys or girls. It appears that the value of each approach is affected by the intelligence of students. Tukey's H.S.D. test was employed to determine what variances among means were significant. The Tukey H.S.D. test was chosen as a post hoc measure because it permitted the experimenter to make all pairwise and contrastwise comparisons and maintain the alpha risk at the .05 level of significance. Results of the Tukey H.S.D. analysis are presented in Figure 5 (see appendix A for computation).
Figure 5

Results of Tukey H.S.D. Post Hoc Analysis on Ordered Means on the Interaction of Sex and Intelligence

\( \Psi \) HSD - \( \alpha \cdot 05 = 5.10 

\[
\begin{array}{cccccccc}
X_{111} & X_{211} & X_{212} & X_{112} & X_{122} & X_{121} & X_{221} & X_{222} \\
43.00 & 41.27 & 41.00 & 39.07 & 28.93 & 24.13 & 23.80 & 22.47 \\
\end{array}
\]

\[
\begin{array}{cccccccc}
\bar{X}_{122} < \bar{X}_{111} & \bar{X}_{121} < \bar{X}_{212} & \bar{X}_{112} < \bar{X}_{212} \\
\bar{X}_{222} < \bar{X}_{212} & \bar{X}_{211} < \bar{X}_{212} & \bar{X}_{112} < \bar{X}_{111} \\
\bar{X}_{222} < \bar{X}_{211} & \bar{X}_{211} < \bar{X}_{111} \\
\end{array}
\]
The Tukey analysis indicates that means need to vary more than 5.10 mean points to be significant at the $P < .05$ alpha level. Results of Tukey's mean gap test indicate that significant differences at the .05 level exist between the means of the low-intelligence, process-taught girls (28.93), and the low-intelligence, content-taught boys (23.80) in favor of the girls group. Low-intelligence, process-taught girls (28.93) achieved significantly ($P < .05$) more science knowledge than did low-intelligence, content-taught boys (23.80) when instructed with a process approach to science rather than a content approach to science. Low-intelligence, process-taught girls (28.93) achieved significantly ($P < .05$) more science knowledge than did low-intelligence girls (22.47) instructed by a content approach. It appears that low-intelligence girls learn more science knowledge when instructed by a process approach than do low-intelligence girls or boys instructed by a content approach. There was no significant difference between low-intelligence boys (24.13) instructed with a process approach and low-intelligence girls (28.93) instructed with a process approach, or low-intelligence boys (23.80) or girls (22.47) instructed with a content approach in achievement of science knowledge. There were no significant differences in the achievement of science knowledge by sex among the high-intelligence groups. A significant difference was found for the main effect of intelligence. High-intelligence students achieved more science knowledge than did low-intelligence students. However, as stated, this effect was not of interest in the study. High intelligence students achieve science knowledge approximately as well whether instructed with a content or process instructional approach.
Interaction of Instructional Approach and Intelligence

An examination of Table 4 indicates that the F ratio for the instructional approach and intelligence to be significant ($F = 4.48$; $df = 1/112$; $P < .05$). As in the previous analysis, the F ratio only alerted the experimenter to the fact that significant differences existed somewhere among the means for the instructional approach and intelligence. To determine specific cell mean differences, additional analysis was needed. First, the cell means for the instructional approach were plotted over intelligence to determine whether the interaction was ordinal or disordinal. Second, Tukey's mean gap test was applied to the means to determine which means varied significantly.

In Figure 6, the cell means for the instructional approach were plotted over intelligence.

Figure 6 shows the interaction of the instructional approach and intelligence to be disordinal. High-intelligence students instructed by a content approach scored higher on the test of science knowledge than did high-intelligence students who were instructed by a process approach. However, the reverse was true with low-intelligence students. Low-intelligence, process-taught students scored higher on the test of science knowledge than did low-intelligence, content-taught students. Tukey's H.S.D. test was applied to determine significant cell mean differences. The results of the Tukey analysis are presented in Figure 7 (see appendix B for computation).
FIGURE 6
Interaction of Treatment and Intelligence
The Tukey analysis of the interaction of intelligence and treatment indicated that means needed to vary more than 3.01 points to be significant at the .05 alpha level. All pairwise contrasts were significant except for the means of the high-intelligence, process-taught students (41.03) and the high-intelligence, content-taught students (41.13). Low-intelligence, process-taught students (26.53) learned significantly more science knowledge ($P < .05$) than did low-intelligence, content-taught students (23.13). Significant differences ($P < .05$) were also noted between the means of both content- and process-taught students from high- (41.08) to low-intelligence (24.83) groups; however, this type of interaction was to be expected. In summarizing the analysis, it can be stated that the instructional
approach used with high-intelligence students does not effect the achievement of science knowledge. However, low-intelligence students achieve more science knowledge when instructed by a process approach than a content approach.

**Intelligence**

The main effect of intelligence, as shown in Table 4, was significant ($F = 385.99; df = 1/112; P < .05$). One would expect that whatever instructional approach was used, high-intelligence students would score higher than low-intelligence students. In the study, the interest was in the interaction of intelligence with other variables and not the main effects of the intelligence variable. The $F$ ratio for intelligence was extremely high ($F = 385.99$); however, when one examines the large gap between mean scores and the closeness of the standard deviations, the large $F$ ratio is understandable.

**Sex/Process - Content**

Table 4 shows that the overall main effect of sex was not significant ($F = .30; df = 2/112; ns$). This result could be expected since the interaction of sex and intelligence was significant ($F = 7.07; df = 2/112; P < .05$). Girls as a group or boys as a group did not achieve more science knowledge through either a content or process approach. When the intelligence and sex variables were included, it was found that low-intelligence, process-taught girls achieved significantly ($P < .05$) more science knowledge than the low-intelligence, content-taught boys or girls. Also, the analysis of the interaction of intelligence and the instructional approach showed that
the process approach to instruction improved the achievement of low-intelligence students in science knowledge.

**Process - Content Groups**

An examination of Table 4 shows that the main effect of the two curricular approaches used was significant ($F = 3.98; \text{df} = 1/112; P < .05$). However, it is not possible to speak of the superiority of one approach over the other since the interaction of intelligence and curricular approach was disordinal in nature. Neither the content approach nor the process approach was superior for all students. As noted earlier, the process approach benefits low-intelligence students in the acquisition of science knowledge; however, neither approach has an advantage with high-intelligence students. The above serves as an example of why interaction effects must be plotted and analyzed prior to main effects.

**Summary**

The purpose of the study was to determine the effects of a process or content curriculum approach on the achievement of science knowledge of fifth grade students taught by one or the other method for five years. The results of the analysis provided the following data for the hypotheses to be tested:

**Hypothesis one** - there will be no differences in the achievement of fifth grade students in science knowledge as measured by the STEP test in science between the groups instructed through a process-oriented approach and the groups instructed through a content-oriented approach---was accepted.
because the results, even though showing significance at the $p < .05$ level between the mean scores in favor of the process approach (33.78) and the content approach (32.16), were "washed out" by the disordinal interaction between treatment and intelligence.

**Hypothesis two** - there will be no differences in the achievement of fifth grade boys in science knowledge as measured by STEP between process-taught boys and content-taught boys—was accepted because the results did not indicate a significant difference at the $p < .05$ level between the mean scores of the process-taught boys (33.57) and the content-taught boys (32.53).

**Hypothesis three** - there will be no differences in the achievement of fifth grade girls in science knowledge as measured by STEP between process-taught girls and content-taught girls—was accepted because the results did not indicate a significant difference at the $p < .05$ level between the mean scores of the process-taught girls (34.00) and the content-taught girls (31.73).

**Hypothesis four** - there will be no differences in the achievement of process-taught fifth grade boys in science knowledge as measured by STEP and process-taught girls—was accepted because the results did not indicate a significant difference at the $p < .05$ level between the mean scores of the process-taught boys (33.57) and the process-taught girls (34.00).
Hypothesis five - there will be no differences in the achievement of science knowledge by low-intelligence, process-taught fifth grade students as measured by STEP and low-intelligence, content-taught students—was rejected because the results showed a significant difference at the $P < .05$ level in the mean score of the low-intelligence, process-taught students (26.53) over the low-intelligence, content-taught students (23.13).

Hypothesis six - there will be no differences in the achievement of science knowledge by high-intelligence, process-taught fifth grade students as measured by STEP and high-intelligence, content-taught students—was accepted because the results did not indicate a significant difference at the $P < .05$ level between the mean scores of the high-intelligence, process-taught students (41.03) and the high-intelligence, content-taught students (41.13).

As shown, the results of the analysis indicated that neither the process nor the content curriculum approach significantly affected the achievement of science knowledge of the fifth grade students studied. When the achievement of students of science knowledge was analyzed in relationship to the sex of the student and the intelligence (high or low), it was found that low-intelligence girls instructed by the process approach achieved more science knowledge than did low-intelligence, content-taught boys or girls. Significant differences were not indicated between low-intelligence girls and low-intelligence boys instructed by the process approach. Neither were there signifi-
cant differences between low-intelligence boys instructed by the process approach and low-intelligence girls or boys instructed by the content approach. Even though low-intelligence boys instructed by the process approach had a greater mean score than the low-intelligence girls or boys instructed by the content approach, the differences were not significant.

Further, analysis of the means of the curricular treatment and intelligence, disregarding the sex of the students, showed that low-intelligence, process-taught students achieved significantly more science knowledge than did low-intelligence students instructed by a content approach to science. Therefore, it appears that a process approach to science enables low-intelligence students to achieve more science knowledge than a content approach. It should be noted, however, that the greater positive change was in favor of low-intelligence girls rather than low-intelligence boys.

The following chapter will present a brief restatement of the purpose, procedures, and principal conclusions of the study. In addition, limitations and implications of the observed findings will be stated, along with suggestions for further study and research.
CHAPTER V

Summary and Conclusions

Purpose

The central purpose of this study was to determine whether fifth grade students taught by a science process approach for five years achieved a comparable degree of science knowledge to fifth grade students taught by a content approach for five years.

Specifically, the study was designed to examine the following hypotheses to determine the effects of two science curriculum approaches—the process approach and the content approach—on the achievement of science knowledge of fifth grade students after five years of instruction:

1. There will be no differences in the achievement of fifth grade students in science knowledge as measured by Sequential Tests of Educational Progress: Science (STEP) between the groups instructed through a process-oriented approach and the groups instructed through a content-oriented approach.

2. There will be no differences in the achievement of fifth grade boys in science knowledge as measured by STEP between process-taught boys and content-taught boys.

3. There will be no differences in the achievement of fifth grade girls in science knowledge as measured by STEP be-
 tween process-taught girls and content-taught girls.

4. There will be no differences in the achievement of process-taught fifth grade boys in science knowledge as measured by STEP and process-taught girls.

5. There will be no differences in the achievement of science knowledge by low-intelligence, process-taught fifth grade students as measured by STEP and low-intelligence, content-taught students.

6. There will be no differences in the achievement of science knowledge by high-intelligence, process-taught fifth grade students as measured by STEP and high-intelligence, content-taught students.

Procedures

In order to examine the hypotheses regarding the effects of the two science curriculum approaches on the achievement of scientific knowledge, the relationships between the test scores achieved by the two groups of fifth grade students on a standardized test, Sequential Tests of Educational Progress: Science (STEP), were analyzed. The two groups of students were randomly selected from each of four elementary schools of the Lakewood (Ohio) Public Schools. The two sets of four schools were selected because one or the other science curriculum approach was used exclusively during the five year period leading to this study.

The process approach. Since 1967 children in four Lakewood Elementary Schools—Grant, Harrison, McKinley, and Roosevelt—have been
instructed in science through a process approach, *Science - A Process Approach*. The American Association for the Advancement of Science developed this program which emphasizes the processes of science in its curriculum design. As participants in the process methodology, the students were taught to use selected processes of science: observing, using space/time relationships, using numbers, measuring, classifying, communicating, predicting, inferring, defining operationally, formulating hypotheses, interpreting data, controlling variables, and experimenting. They were helped to acquire and practice these processes of science as intellectual skills in a manner that would aid them in their future learning in science as well as in other areas. The students learned these skills in a hierarchical manner, later learning building upon earlier learnings. Success did not depend on skill in reading or acquiring a mass of facts but, rather, on the student's ability to use the processes of science.

*The content approach.* Since the early sixties, Lakewood Elementary School children have been learning science through a content approach as prescribed and published by the school system (*Science: Grade One; Science: Grade Two;* etc.), the only exception being the students in the four schools using the process approach started in 1967. These four schools---Garfield, Hayes, Lincoln, and Madison---have continued to use the content approach since that time. The Lakewood program emphasizes content learning or the acquisition and understanding of scientific knowledge and the fundamental principles of science. As participants in the content approach, the students were taught science through a comprehensive and sequentially organized
program centered around a topical framework of recognized science fields. This topical framework in the Lakewood program includes: Living things—plants and animals; non-living things—the earth and the universe, and matter and energy. Controlling concepts are developed for each of these topics which are, in turn, broken down into sub-concepts. Finally, they are reduced to instructional concepts. The Lakewood program is much more inquiry-oriented than the typical content approach and, therefore, may appear to be quite similar to the process approach. However, it is the method and content emphasis which are different. The process approach employs certain science content as the vehicle to teach the science processes whereas the content program uses science processes as the vehicle to teach science content.

**Measurement instruments: the mental ability test.** In order to assist in the randomized selection of students and to be able to divide the students into two groups—high intelligence (115 I.Q. and above) and low intelligence (99 I.Q. and below)—the total I.Q. scores derived from the California Test of Mental Maturity were used. This test is annually administered to fourth grade students in the Lakewood Schools and the students in this study were tested with this instrument, the 1963 edition, S-Form, Level 2, in October, 1971.

**Measurement instruments: the achievement test.** During the eighth month (April) of the students' fifth year of science instruction through a process or content approach, the students randomly selected to participate in the study were given an achievement test in science to determine their acquisition of knowledge of scientific facts, principles, generalizations, and laws. The testing instrument selected was
the Sequential Test of Educational Progress: Science (STEP), Series II, Form 4A, 1969. The STEP test in science was selected because it was considered the best standardized science test available at the time of this study at the elementary level to measure the knowledge of scientific facts. The test is a fifty question, objective, standardized test of science understanding of which fifty per cent of the questions are in the area of biological science, eighteen per cent in earth science, and thirty-two per cent in physical science.

Design of the study. Essentially, a three-stage, stratified, random sampling procedure was employed to select subjects for testing from each of the two science curriculum groups. Basically, there were fifteen students selected for each of four sub-groupings within each curriculum approach used. The two groups of sixty students were selected based on five years of instruction in one or the other approach, sex (boy or girl), and intelligence (high or low). The groupings were established to analyze the effects of the curriculum approach (treatment), intelligence, sex, or a combination of these variables on the students' achievement of science knowledge. A 2 x 2 x 2 hierarchical analysis of variance constituted the statistical design.

Summary of Findings

From the analyses of the data in this study, the following findings may be stated:

1. **Hypothesis one was accepted.** Even though there was a significant difference (at the .05 alpha level) in the achievement of fifth grade students in science know-
ledge as measured by the STEP test in science between the groups instructed in science through a process-oriented approach ($\bar{X} = 33.78$) and the groups instructed through a content-oriented approach ($\bar{X} = 32.16$), this effect was "washed out" by the disordinal interaction between treatment and intelligence.

2. **Hypothesis two was accepted.** There were no significant differences (at the .05 alpha level) in the achievement of fifth grade boys in science knowledge as measured by STEP between process-taught boys ($\bar{X} = 33.57$) and content-taught boys ($\bar{X} = 32.53$).

3. **Hypothesis three was accepted.** There were no significant differences (at the .05 alpha level) in the achievement of fifth grade girls in science knowledge, as measured by STEP between process-taught girls ($\bar{X} = 34.00$) and content-taught girls ($\bar{X} = 31.73$).

4. **Hypothesis four was accepted.** There were no significant differences (at the .05 alpha level) in the achievement of process-taught fifth grade boys ($\bar{X} = 33.57$) in science knowledge as measured by STEP and process-taught girls ($\bar{X} = 34.00$).

5. **Hypothesis five was rejected.** There were significant differences (at the .05 alpha level) in the achievement of science knowledge in favor of low-intelligence, process-taught fifth grade students ($\bar{X} = 26.53$) as measured by STEP over low-intelligence, content-taught
students ($\bar{X} = 23.13$). However, the greater positive change was in favor of low-intelligence girls.

6. **Hypothesis six was accepted.** There were no significant differences (at the .05 alpha level) in the achievement of science knowledge by high-intelligence, process-taught fifth grade students ($\bar{X} = 41.03$) as measured by STEP and high-intelligence, content-taught students ($\bar{X} = 41.13$).

**Discussion and Interpretations**

**Treatment and sex variables.** The analysis of the data showed that after five years of science instruction through a process approach or a content approach that neither group of students achieved greater scientific knowledge because of the curriculum approach employed. Even the study of the sex variable data between the two approaches revealed no significant effects. Without considering the intelligence variable, neither the girls nor the boys of one treatment group or the other achieved significantly more science knowledge because of the curriculum approach. It was an assumption by the investigator, as reflected in the first three hypotheses dealing with the treatment variable and the sex/treatment variables, that neither approach to science instruction at the elementary level would be superior to the other in helping children achieve science knowledge. As determined by the Tukey analysis and graphing procedures of all cell means, the value of the process or content approach for boys or girls was effected by the intelligence factors which will be explained in the next section.
Treatment and intelligence variables. As shown by the Tukey analysis, all pairwise and contrastwise comparisons of the interaction of the treatment and intelligence variables were made and graphing procedures used to determine the significance of cell mean differences. In this analysis, it was found that five of the six cell means were significant.

Even though this analysis showed that the effects on the achievement of science knowledge of high-intelligence students was significant over low-intelligence students in four of the six comparisons of cell means, it was assumed that high-intelligence students would achieve more science knowledge than low-intelligence students because it is an accepted principle that there is a relatively close correlation between student intelligence and academic achievement. Therefore, because this principle was recognized at the outset of the study, the significant effects of the high-intelligence variable were not considered as a factor in the investigation. In the study, the interest was on the interaction of intelligence and the other variables. The exception was the difference in the mean scores between high-intelligence, process-taught students and high-intelligence, content-taught students which showed no significant effects from either curriculum approach. However, in the comparison of cells between low-intelligence groups—process to content—the low-intelligence, process-taught students achieved more science knowledge than the content-taught students. This result might have been expected for the process group because of the involvement of the students with concrete methods of learning and discovery without being required to learn
through reading or other abstract forms.

In summarizing the effects of the intelligence variables on treatment, it can be stated that the instructional approach used with high-intelligence students does not effect achievement of science knowledge whereas in the low-intelligence group the instructional approach does effect achievement in favor of process instruction.

Treatment, sex and intelligence variables. It was indicated in the previous section that low-intelligence students benefitted more from a process approach curriculum than low-intelligence students benefitted from a content approach curriculum in the achievement of science knowledge. It was shown in the analysis, however, that this effect was produced, not by sex alone, but because of the interaction of the sex and intelligence variables. An unexpected result revealed in the findings was the significant effect the process approach had on low-intelligence girls. Low-intelligence, process-taught girls were found to benefit to a significantly greater extent by their curricular treatment than either the low-intelligence, content-taught boys or girls. In fact, the low-intelligence, process-taught girls had a mean score greater than the low-intelligence, process-taught boys but not quite at a level to be significant. One could have assumed that the reverse would have been true for both the low-intelligence, content-taught boys (low, process girls showed significance over) and the low-intelligence, process-taught boys (low, process girls did not show significance over) since it is generally assumed that boys have a greater interest in and facility for science, and have a greater understanding of scientific facts and principles. Partin's (1967) study
supports these generalizations which were upheld in her investigation. Further, boys are generally recognized as having greater difficulty in reading than girls and, therefore, it could be assumed that the process approach (which does not require a great deal of reading) would benefit low-intelligence boys more than the girls.

Conclusions

It can be concluded from this study that the use of a process (inquiry or discovery) curriculum approach in teaching science to elementary school-age children was apparently as effective in their achievement of science knowledge (facts, principles, generalizations, and laws) as was the use of a content (knowledge or concept) approach. One could conclude from this that the curricular approach, in itself, is not the totally most important means by which students learn specific science information. Students may very well be affected by other controlling influences such as outside-of-school forces, self-motivation, and interest. This kind of conclusion may not be considered unusual when considering conclusions of other studies comparing different types of treatment in other areas of curriculum or school organization which show comparable results.

One important finding from this study was the fact that low-intelligence students (99 and below) appear to profit more from a process-oriented approach of science instruction than they do from a content-oriented approach. It can be concluded from this that there is some aspect of inquiry-type learning that provides a more "concrete" structure for the student through which he can see, and feel, and
manipulate and, thereby, establish an understanding of the content. If taught by a more traditional method such as a content approach, it may include too much reading material and teacher lecture which creates a form of learning which is too abstract for the child of lower intelligence. It has been concluded many times before in other studies that "concrete" examples and manipulative devices assist students of lower intelligence in learning.

Another important finding from this study was that low-intelligence, process-taught girls appear to benefit the most from this curriculum approach. The reasons for such a finding are unclear for further studies would have to be made to investigate the cause and effects. However, it can be concluded from this that the girls may very well be more positively affected by "concrete" examples and manipulation which boosted their physical science learnings. Science - A Process Approach uses a high percentage of physical science in their exercises which other studies have reported to be their weakest areas. Further, learning process skills may be more motivational for low-intelligence girls than for boys.

It can be concluded from this investigation that a school system or a classroom teacher of science education choosing between a program emphasizing curriculum content or a program emphasizing curriculum processes might well consider the process-oriented program as being a more favorable form of instruction for all students since it does not adversely affect any group of students and actually is beneficial to low-intelligence students, particularly girls.
Recommendations for Further Study

Several questions may be raised from the findings of this study which may have implications for further research. The first question is concerned with the test instrument used to determine the achievement of science knowledge: is the instrument the most reliable for evaluating the achievement of science knowledge of elementary school students? The second question is concerned with the unexpected greater achievement of low-intelligence, process-taught girls than for low-intelligence, content-taught boys: would an item analysis of specific scientific questions asked on the test reveal the areas of superiority of the girls' achievement over the boys'? The third question is concerned with the longitudinal aspects of the nature of the instructional period and the reliability of the results achieved: are there too many out-of-classroom opportunities for children to learn scientific facts and principles over a five year period other than through classroom instruction? A fourth question is concerned with the criticism of the process approach being non-content oriented: is there more scientific content to the process approach than generally assumed?

A major recommendation growing out of this study is to repeat the study using a measurement instrument which may have greater potential to ascertain the degree of scientific knowledge achieved by elementary-age students. The Comprehensive Tests of Basic Skills: Science, Expanded Edition, Form S (CTBS), 1973, published by McGraw-Hill, Monterey, California, may well be a much more reliable instrument to determine growth in achievement of science content. This instrument was published after this study was completed. It might well open new
avenues to the investigation of content achievement in elementary school science.

Another recommendation is that a study of this nature be repeated to determine in what specific areas of science low-intelligence, process-taught girls excel compared to low-intelligence, content-taught boys. Item analysis of this nature may provide further understanding why low-intelligence, process-taught girls achieved greater science knowledge than did boys. Also, it may be well to investigate any influences the new sex discrimination movement of the past few years has on the achievement of girls.

Since it is recognized that a study of this type has the limitation that the subjects are influenced by out-of-classroom, casual learning from a highly technological, science-oriented society, it is recommended that a study be conducted in which three methods of learning science are employed and subjected to research analysis to determine achievement of science knowledge between the three groups. One group would be instructed through a process approach, one group through a content approach, and one group through a casual, out-of-classroom, incidental approach. This analysis may provide further information on the influences of out-of-classroom learning on the achievement of science knowledge.

Intermittent investigations of the achievement of science knowledge of elementary students might be a better indicator of the influences of out-of-classroom forces. A study of this nature may be repeated with levels of data being provided at the end of each grade level, at the end of two-year periods such as K-1, 2-3, 4-5, or at
the third grade or mid-point.

It would also be of value to investigate the differences in the achievement of science knowledge between a group instructed through one of the more modern content/process approaches and groups instructed through either the content approach or the process approach. Such an analysis may provide information which bypasses the limitation of this study that neither the process approach nor the content approach is absolutely "pure" and can be isolated as the main effect on achievement.
APPENDIX A

TUKEY H.S.D. TEST CALCULATION

Interaction of Sex
and Intelligence
TUKEY H.S.D. TEST CALCULATION

Interaction of Sex and Intelligence

\[ \psi = q_8/0.05/\alpha/B/1/abc(n-1) \cdot \sqrt{\text{MSS/C/AB}/15} \]

\[ 4.36 \cdot \sqrt{20.52/15} = \]

\[ 4.36 \cdot 1.17 = \]

\[ 5.10 \]

\[ \psi = 5.10 \]
APPENDIX B

TUKEY H.S.D. TEST CALCULATION

Interaction of Treatment and Intelligence
TUKEY H.S.D. TEST CALCULATION

Interaction of Treatment
and Intelligence

\[ \Psi = q \cdot \frac{1}{0.05} \cdot \frac{1}{\sqrt{\text{abc}(n-1)}} \cdot \sqrt{\text{MSS}/\text{AB}/30} \]

\[ 3.68 \cdot \sqrt{20.52/30} = \]

\[ 3.68 \cdot 82 = \]

\[ 3.01 \]

\[ \Psi = 3.01 \]
APPENDIX C

MEASUREMENT INSTRUMENT
Please Note:


University Microfilms.
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