R E P O R T   R E S U M E S

ED 020 912   SE 004 010

AN INVESTIGATION INTO THE RELATIONSHIP BETWEEN CONCEPT ATTAINMENT AND LEVEL OF MATURITY.

BY- STAUSS, NYLES G.
WISCONSIN UNIV., MADISON

REPORT NUMBER BR-5-0216   PUB DATE   FEB 68
CONTRACT OEC-5-10-154
EDRS PRICE MF-$0.50 HC-$3.16   77P.

DESCRIPTORS- ACADEMIC ACHIEVEMENT, *CELL THEORY, *CONCEPT FORMATION, *ELEMENTARY SCHOOL SCIENCE, *INSTRUCTION, *LEARNING, SCIENTIFIC CONCEPTS, BIOLOGICAL SCIENCES, CURRICULUM PLANNING, COGNITIVE TESTS, SCIENCE CONCEPT LEARNING PROJECT,

REPORTED IS AN INVESTIGATION OF CONCEPTS INCLUDED WITHIN A CONCEPTUAL SCHEME--THE BIOLOGICAL CELL--WHICH ARE MOST APPROPRIATE FOR STUDY BY CHILDREN IN GRADES 2-6. SUB-PROBLEMS WERE (1) TO DETERMINE THE RELATIVE LEVELS OF UNDERSTANDING AS INDICATED BY OBJECTIVE TEST SCORES, (2) TO DETERMINE WHETHER SIGNIFICANT DIFFERENCES EXIST BETWEEN PUPILS AT DIFFERENT GRADE LEVELS IN TERMS OF THEIR LEVEL OF UNDERSTANDING OF EACH CONCEPT, AND (3) TO DETERMINE THE LEVEL OF UNDERSTANDING WITHIN GRADES OF EACH CONCEPT AS INDICATED BY THE RELATIONSHIP OF TEST SCORES TO I.Q. AND AGE. THE GRADES IN WHICH SATISFACTORY MASTERY OF 11 SPECIFIC CONCEPTS ARE ATTAINED AT THE THREE SPECIFIC LEVELS OF UNDERSTANDING (KNOWLEDGE, COMPREHENSION, AND APPLICATION) ARE OUTLINED. IT WAS DETERMINED THAT MANY OF THE CONCEPTS COULD BE TAUGHT SUCCESSFULLY IN THE LOWER ELEMENTARY GRADES. HOWEVER, IT IS INDICATED THAT THE SELECTION OF CONCEPTS TO BE INCLUDED IN THE CURRICULUM SHOULD BE BASED ON THE LEVEL OF MASTERY DESIRED--KNOWLEDGE, COMPREHENSION, OR APPLICATION. THE INSTRUCTIONAL PROGRAM UTILIZED IN THE STUDY IS AVAILABLE AS PRACTICAL PAPER NO. 2 OF THE CENTER. (DS)

BR-5-0216
PA-24

AN INVESTIGATION INTO THE RELATIONSHIP BETWEEN CONCEPT ATTAINMENT AND LEVEL OF MATURITY

RESEARCH
COGNITIVE LEARNING
DEVELOPMENT

CENTER FOR
COGNITIVE LEARNING

Technical Report No. 40

AN INVESTIGATION INTO THE RELATIONSHIP BETWEEN CONCEPT ATTAINMENT AND LEVEL OF MATURITY

By Nyles G. Stauss

Report from the Science Concept Learning Project

Milton O. Pella and George T. O'Hearn, Principal Investigators

Wisconsin Research and Development
Center for Cognitive Learning
The University of Wisconsin
Madison, Wisconsin

February 1968

The research reported herein was performed pursuant to a contract with the United States Office of Education, Department of Health, Education, and Welfare, under the provisions of the Cooperative Research Program.

Center No. C-03 / Contract OE 5-10-154

PREFACE

Contributing to an understanding of cognitive learning by children and youth—and improving related educational practices—is the goal of the Wisconsin R & D Center. Activities of the Center stem from three major research and development programs, one of which, Processes and Programs of Instruction, is directed toward the development of instructional programs based on research on teaching and learning and on the evaluation of concepts in subject fields. The staff of the science project, initiated in the first year of the Center, has developed and tested instructional programs dealing with major conceptual schemes in science to determine the level of understanding children of varying experience and ability can attain.

The instructional program for Grades 2-6 tested in this study utilized the conceptual scheme the biological cell. It was found that many of the concepts could be taught successfully in the lower elementary grades. It was pointed out, however, that the selection of concepts to be included in the curriculum should be based on the level of mastery desired (knowledge, comprehension, or application). The instructional program utilized in the study described in this report is available as Practical Paper No. 2 of the Center.

Herbert J. Klausmeier
Director

CONTENTS

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF GRAPHS

ABSTRACT

The focus of this study was the identification of the concepts included within the conceptual scheme—the biological cell—most appropriate for study by children in Grades 2 through 6.

Subproblems were: 1. to determine the relative levels of understanding as indicated by objective test scores, 2. to determine whether significant differences exist between pupils at different grade levels in terms of their level of understanding of each concept, and 3. to determine the relationships within grades of the level of understanding of each concept as indicated by test scores to IQ and age.

The concepts selected were ordered as below.

1. Cells are parts of living things and living things only.
2. Cells have a basic structure.
3. The parts of cells have specific functions.
4. Plant cells differ in structure depending upon their function.
5. Animal cells differ in structure depending upon their function.
6. The activities associated with life are carried on in the cell.
7. Organisms differ in size depending upon the number of cells possessed, not the cell size.
8. Cells come from previously existing cells as a result of the process of division.
9. DNA is the important molecule concerned with regulation of cell activities.
10. DNA replicates itself and also serves as a template for RNA formation involved in regulation of cell activities.
11. Cells cannot grow to indefinite size.

Instructional materials were developed and utilized in teaching one class each at Grades 2 through 6. Achievement was measured utilizing multiple responses, multiple choice type questions.

The grades in which satisfactory mastery of specific concepts is attained at the three levels of understanding are:

Concept 1. Knowledge, comprehension, and application. Grades 2-6.
Concept 2. Knowledge. Grades 2-6. Comprehension. None. Application. Grades 4-6.
Concept 3. Knowledge and comprehension. Grades 2-6. Application. Grades 4-6.
Concept 4. Knowledge. Grades 2-6. Comprehension and application. Grades 3-6.
Concept 5. Knowledge. Grades 2-6. Comprehension. Grades 3-6. Application. Grades 4-6.
Concept 6. Knowledge, comprehension, and application. Grades 2-6.
Concept 7. Knowledge. Grades 2-6. Comprehension and application. Grades 4-6.
Concept 8. Knowledge. Grades 3-6. Comprehension and application. Grades 4-6.
Concept 9. Knowledge and comprehension. Grades 2-6. Application. Grades 3-6.
Concept 10. Knowledge. Grades 3-6. Comprehension. Grades 4-6. Application. Grade 6.
Concept 11. Knowledge. Grades 4-6. Comprehension. Grades 5 and 6. Application. None.

I

THE PROBLEM: ITS BACKGROUND AND ITS NATURE

INTRODUCTION

> Concepts have been cited as the products of scientific processes, as the basis for further scientific study, and at times as the knowledge that is applied by the technologist....
>
> Concepts are important not only because they are the warp and woof of science, but also because they provide the possessor with a means of coping with the development of knowledge in the future. It seems that one way known to provide for maximum coverage of old and new knowledge is through the development of a classification system. The formation of concepts or conceptual schemes is one method of classification which results in such economical use of human intelligence. (Pella, 1966)

The value to pupils of developing concepts rather than memorization of facts has been recognized for many years (31st Yearbook NSSE, 1932). In spite of this the use of science concepts and conceptual schemes have only recently become the focus for science curriculum development and teaching. It is also only recently that scientists and educators have come to recognize that the rate of growth of knowledge in science is so great that "learning it all is impossible if not unwise to attempt."

Concepts in science have been defined and described in a variety of ways depending upon the background of the scholar. If the scholar is a psychologist the descriptions are concerned with perception (Hunt, 1962; Woodruff, 1951; Kranzer, 1963; Klausmeier and Goodwin, 1966). If the scholar is a scientist the concern is more with the nature of the concept and its method of evolution (Conant, 1951; Einstein, 1938).

In this study a concept is viewed as "a summary of the essential characteristics of a group of ideas and/or facts that epitomize important common features or factors from a larger number of ideas." (Pella, 1966) These concepts involve the development of classification or descriptions of objects or phenomena in nature, the relating or correlating of one or more facts with other facts, and the development of theories useful in explaining observations.

The characteristics of concepts accepted are:

1. Concepts are ideas possessed by individuals or groups. They are a type of symbolism.
2. Concepts of any particular object, phenomena, or process exist in a continuum from simple to complex.
3. Concepts emerge as a result of experience with more than one object, phenomenon, or fact. They are generalizations.
4. Concepts are the result of abstract thinking that embraces the many experiences.
5. Concepts involve the relating of facts or supposed facts to each other by the individual.
6. Concepts are not always based upon a physical encounter.
7. Concepts are not inherent in nature or reality.
8. Concepts are not photographic images of reality.
9. Concepts are neither true nor false; they are, rather, adequate or inadequate.
10. Concepts have five primary relationships: relations to people, relations to things, relations to other concepts, relations within conceptual systems, and relations to processes.
11. Concepts are useful in making predictions and interpretations.
12. The individual concepts formed in any area may be determined by the sequence

of the sensory experiences received or available.

13. The individual concepts formed in any area may be determined by the cultural pattern at the time of formulation. As the culture changes, the meaning and value of a given concept may change.
14. The nature of a concept may be determined by the procedure that led to its formulation.
15. Concepts and conceptual schemes are rendered inadequate as a result of new knowledge and must undergo constant revision. (Pella, 1966)

Because of the variety of types of concepts, the variation in complexity of concepts of each type, and the relationship of other factors to concept development in science, it is valid to objectively examine some aspects of concept learning in science.

David P. Ausubel (1963) stated: "We desperately need studies indicating that certain kinds, components, and levels of subject matter which cannot be learned efficiently at one age level can be learned efficiently at another age..."

THE PROBLEM

The identification of the concepts included within the conceptual scheme—the biological cell—most appropriate for study by children in Grades 2 through 6.

SUBPROBLEMS

1. To determine the relative levels of understanding as indicated by objective test scores of pupils in Grades 2 through 6 of eleven concepts selected from the conceptual scheme—the biological cell.
2. To determine whether a significant difference exists between pupils at different grade levels in terms of their level of understanding of each of the 11 concepts.
3. To determine the relationship within grades of the level of understanding of each concept, as indicated by test scores, to IQ and age.

HISTORICAL BACKGROUND

Science teaching, like every other teaching area, had its origin in the disciplines themselves; the nature of the science during an era is reflected in the teaching of science during that era. Science has emerged from the stage of classifying and describing natural phenomena and objects, through the stage during which the correlation of observations one with another was of prime importance because of the concern for cause and effect relationships in nature, to the present stage where most emphasis is placed upon theory development. The concepts making up the science curriculum during each phase reflect this predominant interest.

Increased growth rates in the development of new knowledge in the many scientific disciplines have made more evident the need for teaching and learning that makes allowances for changes in a body of knowledge. The teaching of identified concepts in science is a part of the attempt to meet this need. The move is from emphasis on the learning of facts to more comprehensive blocks of less specific knowledge.

Underhill (1941) states that the majority of books, of the early and mid-1800's, were characterized by their emphasis on unrelated and isolated bits of information, without any suggestion of observational procedures, or any attempts to build a conscious realization of an organized body of content, nor of the processes by which scientific knowledge is gained and/or formulated.

The late 1800's saw the influence of Herbartian philosophy which directed attention to ideas and their relationships and the traditional method of organization of subject matter was not viewed with favor for elementary school science. Theories of the Herbartians led to a more generalized approach, and to a breaking down of subject matter boundaries. William T. Harris, often credited with establishing the first elementary science curriculum, agreed with some of the basic Herbartian philosophy concerning the importance of emphasizing relationships of ideas in making learning meaningful (Underhill, 1941). He, however, preferred to work within the framework of subject matter organization.

Another aspect of science teaching, that which transcends the boundaries of the specific discipline, was championed by Charles McMurry (Underhill, 1941). He saw unity in the generalizations in each science discipline and also in the intimacy of their relationships to one another. (This latter approach may be compared to that expressed recently in NSTA's *Theory Into Action*, 1964,) It remained for Jackman to formulate the first real plan to emphasize the generalizations of science as guiding principles of organization (Underhill, 1941).

The rise of early giants of psychology, such as G. Stanley Hall, and the rise of Freudian influence shifted teaching emphasis somewhat, although there is no evidence that the public elementary schools ever became involved to any great extent in these extreme moves.

The reports of the NEA Committee on Secondary School Studies (1893), while directed at the secondary school, did have some influence on the elementary school and briefly set down recommendations for the study of science by observation and experimentation. However, in light of the continued favor of faculty psychology and its emphasis on guidance of the child to train specific faculties, rote fact-learning continued dominant. Underhill (1941) lists a premise accepted at this time, that the faculties involved in generalization could not be exercised in young children and therefore there could be no science (not referring to nature study) in the elementary school.

During the 1920's a resurgence of the idea of using science generalizations in teaching occurred (generalizations being interpreted here as broad conceptual schemes). The report of the NEA Commission on the Reorganization of Secondary Education (1918), entitled "Cardinal Principles of Secondary Education," had emphasized science generalizations as functioning in satisfying the needs of the child in society. This emphasis continued during the 1920's under the guidance of Craig and others and reached a temporary climax with the NSSE 31st Yearbook (1932) and its recommendations for teaching of the generalization of science.

The NSSE 46th Yearbook (1947) listed among its objectives for elementary science the use of "functional concepts" and "functional understanding of principles." The use of the term "functional" in regard to many of their objectives perhaps is due to the appearance during the 1930's and early 1940's of the Life Adjustment philosophy in education. This may be recognized in the following excerpt:

> To recognize information as an objective of science education, as is here done, is not to endorse the acquisition of a body of isolated facts whose usefulness is limited to the particular science period in which they are learned or recited. On the contrary, the information learned must result in altered thinking and in altered behavior. It must make the pupil (and later, the adult) more intelligent and readier for adequate adjustment whenever that information is relevant to life situations.

Continued emphasis on concepts is also shown by the following statements:

> Science concepts and principles must also be taught so that they will be *functional.* . . . It is one thing to be able to recite a neat statement covering a concept. It may be something else to be able to use the concept correctly in thinking, speaking, or writing about a relatively unfamiliar situation in which the concept properly plays a part.
>
> The critical element in functional concepts and principles, as in functional information, is understanding.

Thus, it is seen that the emphasis on concept learning was oriented toward life-function.

Approaching the 1950's, the pendulum briefly swung in the other direction with most emphasis on the factual. By the 1960's, however, commitment to the conceptual schemes approach was renewed. With the tremendous expansion of scientific knowledge during the past decade, scientists and science educators are in substantial agreement that no one can learn all there is to learn, fact-wise, in even a very narrowly defined discipline within science. Our only hope, according to these people, lies in the attempt to formulate broad conceptual schemes whereby the child can come to an understanding of nature. As Nash (1963) remarks:

> Nobody today can master all of science because nobody today lives long enough to master the arts of all scientific theories. But he who has mastered a few major theories does thereby come most literally to *comprehend* certain entire domains of his experience.

COMPATIBILITY OF CONCEPT LEARNING AND THE PHILOSOPHY OF SCIENCE

To justify the use of concepts and broad conceptual schemes in the teaching of science for whatever external aims one may wish to set up, a look should be taken at the nature of science. For a time during the 19th century, many scientists felt that science was a matter only of seeking out and reporting the facts in nature. This view is not what most scientists would accept today. For as Shamos (1960) says: "Perhaps the greatest injustice that can be done to science is to regard it merely as a collection of facts. . . . Facts alone do not constitute a science." Man continuously works at discovering more and more information about nature, not for the mere purpose of discovering isolated bits and pieces, but rather, to form an understanding of nature by discovering relationships which exist.

Bronowski (1956) calls science "the search to discover unity in the wild variety of nature." Lachman (1960), Holton and Roller (1958), and others, express the same basic philosophy of science when they emphasize that the goal of science is to facilitate an understanding of the universe, that is, "To provide 'explanations' for . . . phenomena by designating relationships which exist between them [Lachman, 1960]." At times it is necessary to go beyond the immediate and the visible, in formulating theories which will attempt to explain the facts of our universe. As Popper (1959) says, "Theories are nets cast to catch what we call 'the world': to rationalize, to explain, and to master it. We endeavor to make the mesh ever finer and finer." Science is thus more than gathering facts or even more than methods of inquiry. Muller (1963) says that "Ultimately the unity of science lies in the logic not the materials or the specific techniques of inquiry." Conceptual schemes are the results of efforts to achieve this unity of science by seeking to establish relationships between observables.

The isolated, unrelated facts do not serve as a suitable basis from which the child can generalize to new situations. Concepts and conceptual schemes serve as unifying threads by which the child may be able to generalize to new situations, and thus serve to free the child from the necessity of first-hand experience of all possible stimuli of nature.

The conclusions of science are tentative and subject to change as new discoveries are made. Man depends upon the development of theories and generalizations into which the facts of today can be fitted and which can be adjusted, modified, and reformulated as continued probing of nature yields closer and closer approximations to reality.

PSYCHOLOGICAL CONSIDERATIONS FOR CONCEPT LEARNING

The idea of concept learning raises many questions concerning the psychological development of the child and the relationship of this development to the ability to theorize and work with abstractions. What are the developmental steps through which the child passes and at what ages can one expect the child to be successful in conceptualizing and comprehending the broad relationships which connect the phenomena of science? In order for concepts and conceptual schemes to be of value in science instruction in the elementary school, the child must have attained the necessary stage of development.

During the late 1800's and early 1900's when faculty psychology was operative, it was postulated that the faculties involved in generalizing were not operative in small children. The ability to generalize or reason was assumed to begin somewhere around the age of the fourth- or fifth-grade child.

It must be remembered that this is from the viewpoint of faculty psychology. The failure to reason and think was due to the fact that the child's maturation had not reached the point where these special faculties were sufficiently developed. Although no longer following this psychological theory, one can see the continued presence of this problem of maturation.

Thorndikian psychology (S-R) did not alter the situation to a great extent. Although theoretically reduced to a matter of simple stimulus-response connections, the general development or maturation of the nervous system still served as an explanation. If reasoning could not as yet be accomplished at a given age, it was basically due to a failure to make the proper S-R connections caused by an insufficient development of the neurological processes. Thus the idea of utilization of generalizations or conceptual schemes would not be considered compatible with this psychological theory.

Is the conceptual schemes approach compatible with today's theories of psychological development and learning? It has been repeatedly stated by Piaget, Inhelder, and Hunt that the elementary school child is not capable of abstract thinking. This does not rule out the conceptual schemes approach. Consider the basic stages of development of the school-age child that are visible from Piaget's work and then see how concept learning and use of conceptual schemes can be fitted to this pattern.

The first stage, up to approximately seven or eight years of age, is the stage in which concrete experiences form the basis of learning (Stendler, 1962). During the balance of the elementary years the child is able to see relationships more and more; at first by mentally referring to concrete experiences and finally by reasoning without such constant referral. At adolescence (approximately 12 to 14 years of age), according to Piagetian theory, the youngster "can cope with problems abstractly and discover laws to explain phenomena, for he can see the structural whole [Stendler, 1962]."

From this one might gather that in the elementary school the child is not capable of dealing with the abstractness often associated with concepts and conceptual schemes. But concepts and conceptual schemes are not all of the same level of sophistication. Concepts may range from the descriptive level to the theoretical. Conceptual schemes vary in complexity from some of the simpler relationships between a very few concepts to highly theoretical constructs. Thus concepts and conceptual schemes can be employed over a wide range—the entire range of development of children found in the elementary school—provided an effort is made to order the concepts and schemes in some hierarchy of increasing complexity, from the relatively concrete to the abstract, and to introduce these to the children at the appropriate stage of development.

Even at the very early age levels children can do some generalizing when confronted with certain pieces of information from which to develop a statement of relationship. Haupt (1935) has shown that the only difference existing in the ability over a range of age groups is a difference in level of sophistication of the statement. Croxton (1936) attributed differences in ability to generalize to differences in experience. This experience factor is also supported by Butts (1963), and Peel (1964). Peel reports that science education in the primary schools should be based on experience leading to the formation of concepts. As more of these concepts are understood, relationships can be determined which will allow the child to weave these into more and more highly sophisticated schemes. How much of this can be accomplished by the child alone is open to question, but Piaget has pointed out that the child can be led to this.

Failure at a given age level does not preclude the possibility of success in future attempts at that age level. Piaget, for example, points out that maturation is a tremendously important factor, but cites the fact that experience results in a variance. Lovell (1966), in discussing Piagetian theory, also points out a most important factor, that of the cultural milieu. Inhelder and Piaget (1958) say that the age of 11-12 years (which they consider as the beginnings of abstract thinking)

> may be, beyond the neurological factors, a product of a progressive acceleration of individual development under the influence of education, and perhaps nothing stands in the way of a further reduction of the average age in a more or less distant future.... the maturation of the nervous system can do no more than determine the totality of possibilities and impossibilities at a given stage [p. 337].

The realization of this maturation can thus be "... accelerated or retarded as a function of cultural and educational conditions."

From the point of view of current psychological theory concerned with concept learning, the use of concepts and conceptual schemes is appropriate even at the elementary school level. It is essential, however, that an effort be made to organize the materials in a sequential manner, from simple to complex.

THE BIOLOGICAL CELL AS A BASIC CONCEPT IN SCIENCE

"The biological cell as the structural unit of living things" is a fundamental concept. The cell is a "unit of structure" which man has defined. Swanson (1964) says:

> the "things" we observe we attempt to define in terms of *units*, and the more refined our knowledge and the more powerful and discriminating our instruments and techniques, the more precise become our definitions of these units, i.e., their limits and basic nature.

Thus, as man's tools for discrimination and his techniques became more powerful and refined, he discovered that the unit "cell" was composed of smaller units. One can remove from the cell certain parts for analysis. The reality of these smaller parts can be observed and demonstrated by anyone possessing proper knowledge and adequate instruments.

While subcellular structures exist in the living organism, many of them carrying on activities of their own, these structures and their activities do not constitute life. If one disrupts a cell by extracting selected parts, both the parts and/or the remains may continue their activities for a time. However, neither is capable of continuing life indefinitely. It is the activities of the parts and the interrelationships of these activities which result in the phenomenon referred to as "life." Since these normally occur and are able to continue only in the intact cell, the cell is considered to be not only the basic structural unit of living things, but is also spoken of as a "functional unit."

Considering the cell as an existing reality, the term "cell theory" is somewhat misleading. "Cell theory" no longer refers to the postulation of the existence of cells, but rather to the entire expanse of thought associated with the cell. Even so, "theory" seems more a matter of conventional use, although it does leave the impression of freedom and latitude to change some of our thinking concerning the cell as new information is discovered.

The ideas expressed in the cell theory form a keystone in biological thought. No other idea in biology is so basic, so fundamental. It can be said without reservation that "we understand life itself only to the extent that we understand the structure and function of cells [Swanson, 1964, p. 4]." As such a fundamental concept of biological science, it demands a prominent place in the teaching of science.

DEVELOPING A CONCEPT OF THE BIOLOGICAL CELL

In the formulation of a concept of the biological cell, it is necessary to consider both structural and functional aspects of the conceptual scheme of the biological cell. These are comprised of concepts of various levels of complexity from the purely descriptive, through the correlational, to the theoretical.

Structural characteristics of the cell, made visible with the aid of the microscope, can be described with some degree of precision and form what might be referred to as the descriptive concepts of the cell. This, however, precludes the problem of artifacts which are often encountered due to the necessity of certain preparation techniques essential to proper viewing of the cell structure.

Other aspects of the cell exist which go beyond the descriptive phase. Relationships exist between the structure of the cell and the function of the cell. These might be referred to as correlational concepts concerning the cell. Concepts range from the simple, well-defined and researched relationships to the complex and highly theoretical. Many of these theoretical aspects concern enzymatic interactions which in turn involve elements of structure at the molecular level. Much of the work at this level is in the realm of theory.

Thus, it can be seen that the scientist's concept of the biological cell incorporates descriptive and correlational, as well as theoretical, elements. There is often no clear separation between these, rather a transition zone where one evolves into the other.

How does the child form a concept of the biological cell? As pointed out at the beginning of this chapter, because of the microscopic size of cells, the child is not cognizant of their existence even though they are the basic units of structure and function of his own body. Thus, the first step in developing a concept of the cell must be the development of an awareness of their existence. Further investigation and study of structure, function, etc., will serve to broaden the child's understanding, forming a more adequate concept. It is obvious that at no time can it be said that one's concept of the cell is complete, nor, that there exists *the* concept of the cell, because in doing so, the implication would be made that man has a complete understanding of all aspects of cell structure and function and no more remains to be discovered.

II

REVIEW OF RELATED STUDIES

INTRODUCTION

The need for additional studies on concept grade-placement has long been recognized. McCarthy (1952), in discussing his own study, stated: "Similar investigations could establish the suitability of other scientific concepts for definite grade levels. It is obvious that tens of thousands of such investigations could be planned and carried out."

Beauchamp (1938) wrote:

> There must be proper gradation of concepts. Only poor thinking and wrong attitudes can develop when the material is too difficult or the child lacks the needed background. The criterion which shall govern the grade placement of content is: Can the concepts be taught to a point of functional understanding? That is, can they be used by the child in daily thinking in solving problems?

The lack of sufficient experimental work in this regard was deplored by Bailey (1941).

> Very little has been done experimentally to determine the learnability of the great mass of content which has been placed in the public school curriculum. Placement of topics or principles in the various courses is usually determined by the logical demands of the subject rather than by the psychological characteristics of the learner.

Many studies concerning concept learning have been carried on over the years. Some were designed on the basis of "the logical demands of the subject," while others were concerned with only the "psychological characteristics of the learner." Such studies have made important contributions to our understanding of concept learning, but only when investigators involved in concept learning studies become mindful that the assumed logic of the discipline and the psychological characteristics of the learner must be considered together can meaningful progress occur.

Concept studies in the area of elementary science teaching have generally been of four main types.

(1) Investigations concerned with the formulation and/or evaluation of psychological hypotheses concerning children's ability to conceptualize. These have often utilized science concepts as a vehicle but have not had as their primary objective the determination of when and/or whether specific science concepts can be learned.

(2) Survey studies in which the opinions of teachers, science teaching specialists, scientists, etc. are sampled concerning the science concepts which they feel should be taught in the elementary science curriculum and also the grade-placement of these concepts.

(3) Attempts to determine the extent of the children's knowledge and understanding of particular concepts, without specific prior instruction as part of the investigation, through evaluation procedures involving:
   (a) clinical procedures, and/or
   (b) written tests, objective and/or subjective, for larger groups.

(4) Determinations of the children's knowledge and understanding of a particular concept *after* specific instruction. Evaluation may again be similar to that described in (3).

The current investigation is of the fourth type in which the children were given instruction on specific concepts, followed by evaluation utilizing written tests. A few typical studies of the first three types will be cited, followed by a discussion of other investigations similar to the current study.

PSYCHOLOGICALLY ORIENTED STUDIES UTILIZING SCIENCE CONTENT

A series of classical studies consistently referred to during discussions of concept learning is that of Jean Piaget. Various concepts from science and mathematics were utilized in his research which resulted in the formulation of his theory of cognitive development.

As a result of his investigations with children, utilizing clinical procedures, Piaget (1964) formulated four "stages" of development. These were:

1. Sensory-motor, pre-verbal
2. Pre-operational representation
3. Concrete operations
4. Formal or hypothetic-deductive operations

While he described these as definite stages in development, he concluded that there is no set age at which children pass from one stage to another. Many factors are involved including maturity, experiences, cultural milieu, etc.

It is against the background of this research that many concept studies operate. The ability of a child to attain an understanding of a scientific concept at a specific level of sophistication might thus be a factor of his "stage" of development.

Oakes (1947), who referred to his own study as "a further extension of Piaget's work," collected data by individual questioning of 153 children (kindergarten, 77; Grade 2, 24; Grade 4, 24; Grade 6, 28) to determine the nature of their explanations of natural phenomena. His study differed somewhat from Piaget's in that Oakes attempted "to analyze the nature of the responses themselves rather than to present an interpretation of the workings of the child's mind." He concluded:

> Certain psychologists, especially Piaget, are convinced that the nature of the child's mind is such that instruction relating to natural phenomena is largely futile. Data bearing on this problem, presented in this study, seem to indicate the opposite conclusion [p. 2].

Susan Isaacs (1930), in discussing results of her study in Cambridge, England, felt that Piaget's conclusions regarding mental stages were not borne out by her data. She concluded that many dissimilar types of behavior could exist in the same child.

Conclusions of other investigators also disagree with Piaget's findings of "stages" in children's cognitive development. Deutsche (1937) working with 732 children in Grades 3 through 8, studied the development of children's concepts of causal relations. She found no evidence of "stages" of development in children's reasoning.

King (1965) conducted a study involving 1235 children, ages 6 to 11. In discussing a part of his study involving the distinction between animate and inanimate things, he stated, ". . . there was no evidence of Piaget's stages of development but only a gradual development of the reasoning processes by more systematic organisations of concepts." Based on his findings regarding questions on sky and night, he concluded that: "Experience in and out of school and a vocabulary increasing with age seemed to be the main factors that determined the types of answers given by boys and girls. . . ."

GRADE PLACEMENT BY CONSENSUS OF EDUCATORS AND SCIENTISTS

Studies of this type generally involve the formulation of a questionnaire which is then sent to a relatively large number of teachers, elementary science specialists, educators, scientists, etc. to obtain their opinions regarding the importance, appropriateness, and grade placement of specific science concepts in the elementary science curriculum. Lists of concepts gathered from current textbooks may be included and the individuals asked to indicate their opinions, or the individuals may be asked to list concepts on their own. While a consensus of opinions based upon experiences of many individuals may serve as a starting point for curriculum construction, the opinions generally are not based upon sound research evidence and therefore lack research validity.

An example of this type of study is one carried out by Leonelli (1955). Three basic questions were asked:

(1) What physical science principles should be included in the curriculum from Grades 1 to 6?
(2) What is the reason for the inclusion of the principle?
(3) In what grade or grades should the principle be introduced?

One hundred forty-eight teachers and elementary science specialists were asked to complete the survey (84 complied on the survey of principles and the "why" for inclusion; 80 participated in grade placement of principles).

A total of 81 principles were listed for their consideration.

A majority of the specialists favored the retention of 48 principles while a majority of the teachers favored the inclusion of 72 of the 81 principles. A list of aims or objectives provided as a check list for determining the reason for inclusion, showed that the respondents felt the chief aim was for interest in and interpretation of the environment.

The portion of the survey concerned with grade placement of the principles indicated a lack of agreement for any given grade. Certain grade areas could be designated, however, since many respondents had indicated introduction of a principle in two successive grades.

DETERMINATION OF THE EXTENT OF CHILDREN'S KNOWLEDGE AND UNDERSTANDING OF SCIENCE CONCEPTS (NO TEACHING)

In this type of study the investigator attempts to determine the children's knowledge and understanding of certain science concepts and their capability of explaining certain natural phenomena as a result of past experiences, including education. No direct teaching is involved in the investigation and the objective is to determine the child's present status rather than to determine whether he could learn the material were it presented to him.

McNeil and Keislar (1962) conducted a two-part study, the first phase of which was the "Analysis of Children's Explanations of Certain Natural Phenomena." A randomly selected group of 72 pupils from the lower elementary classrooms was interviewed individually "to determine their conceptualizations of certain natural phenomena." The questions concerned the phenomena of condensation and evaporation. They found that: "Almost without exception, perceptual (direct, sensory) approaches rather than theoretical solutions predominated. Third graders had more explanations than first."

Inbody (1963) conducted a study on "Children's Understanding of Natural Phenomena" with 50 kindergarten children. He selected 16 physical phenomena determined by investigating widely used textbooks for Grades K-2. The children were individually questioned using a demonstration-interview technique.

The basic procedure used was:

> (a) showing the child certain materials and asking him to predict what would happen under given circumstances,
> (b) performing the demonstration and having the child state what happened, and
> (c) eliciting the subject's explanation of the phenomenon.

Inbody concluded:

> There seems to be little doubt that the nature of children's thinking changes with maturity and experience. It also seems that the kind of thinking a child can do at any given time places limitations on the type of instruction he can profitably utilize. . . . Evidence produced in the present study has shown that young children are capable of understanding cause and effect relationships. It has also shown that adult logic is often meaningless to children, and may well lead to overgeneralization and verbalization.

In another study, Haupt (1952) sought to determine grade and age differences in children's experiences with, and explanations of, magnetism. He also sought to determine whether children's concepts of magnetism parallel the historical development of man's knowledge of the subject. Twenty-five children from Grades 1-7 were questioned individually while being allowed to play with magnets and materials. The concepts were presented to the children through the use of appropriate questions.

Haupt concluded: "This study of parallels of children's thinking with that of the race reveals primitive ideas that are used to conceptualize the raw data of experience." Concerning "laws of magnetism," he stated: "This particular array of data seems to indicate that the children in the lower grades have attained to concepts that are equivalent in complexity and maturity to those from the children in the higher grades." On the "theory of magnetism" his examples reveal that the lower grades probably approximate primitive ideas more closely. There is not much difference, however.

DETERMINATION OF CHILDREN'S KNOWLEDGE AND UNDERSTANDING OF SCIENCE CONCEPTS AFTER INSTRUCTION

A second phase of the study by McNeil and Keislar (1962) involved the instruction of six first-grade pupils, representing a range in intelligence and knowledge of scientific vocabulary, in certain molecular concepts. Each pupil was given individual instruction of 13 sessions of 10-15 minutes each. The control group, match-paired on sex, intelligence, and scientific vocabulary, received no instruction.

Evaluation was done by interviewing each child (experimental and control) and asking him to explain instances of evaporation and condensation. No pupils from the control group were able to give answers to questions dealing with the relation of molecules and states of matter. The members of the experimental group could answer questions which dealt with content similar to that used in the instructional materials, but they could not generalize to new instances.

> There was no evidence that when attempting to explain unexamined but familiar instances of evaporation and condensation, experimental subjects could use the theoretical principles taught.... For the most part, subjects in both groups continued to explain phenomena at concrete and functional levels.

J. Myron Atkin (1961) investigated children's reactions to the study of certain topics which were deemed basic to modern astronomy by professional research astronomers. Instructions were prepared and groups of fourth, fifth, and sixth graders with IQ's greater than 105 were given about 25 sessions of about 45 minutes each.

Conclusions of significance to the current investigation were:

> (1) It appears that children can learn astronomy concepts deemed fundamental to the science even if these concepts are not perceived as closely related to their personal and social needs.
>
> (2) Children's interest in learning such concepts can be very high in the elementary-school age range.
>
> In the view of all the observers (many of them regular elementary-school classroom teachers), children can learn modern astronomy. There is no compelling reason to be satisfied with the solely descriptive.

In another study, Nelson (1960) investigated the problem of how children acquire concepts, the level of their understanding, and whether socio-economic background and intelligence are related to this learning. One hundred eighteen boys and girls from the intermediate grades were given pretests, instruction on concepts of light and sound, and then posttests.

Among the conclusions noted were:

1. Instruction produced a significant increment in the understanding of principles related to Light and Sound.
2. The Sound Test showed a significant improvement directly related to the grade of the pupil.
3. Grade and social status are not related to the amount of improvement on the various tests, but they are directly related to the level of performance, both before and after instruction.
4. All tests are significantly related to one another and to intelligence.

Oxendine (1958) investigated "The Grade Placement of the Physical Science Principle 'Sound is Produced by Vibrating Material' in Relation to Mental Ages." Seven hundred students from the fourth and sixth grades from 15 elementary schools of the New England area were involved in the study.

The experimental groups were given a lecture-demonstration on the science principle. Test results showed that at the mental age levels of 11-12 years pupils attained a mastery of the test. Pupils of the fourth grade were not ready for the instruction. At the sixth grade, 57% of the pupils mastered the test.

Working with fourth-, fifth-, and sixth-grade students concerning their understanding of certain atomic energy concepts, Reid (1954) found that children in all grades showed significant gains after instruction. The groups gained and showed more understanding with maturity, sixth grade scoring highest and fifth next. The children from the fourth grade experienced the most difficulty.

Harris (1964), in attempting to develop techniques to overcome the teacher variable in grade-placement research through the use of teaching tapes, utilized concepts basic to the molecular or kinetic theory of heat. He worked with students from Grades 4-6 using an oral evaluation.

He concluded that the fifth and sixth grades were appropriate levels for the placement of certain concepts of the molecular or kinetic theory, but that most concepts would be inappropriate at the fourth grade.

A summarization of more than 20 grade-placement studies at Boston University, involving physical science principles, was made by Read (1958). He concluded, "Without minimizing the importance of other factors, grade level can be said to be important indeed." Much of this he attributes to the factor of added experience which is a result of increased age. "Nevertheless," he stated, "maturation seems to be established as a major factor."

Studies concerned with the grade placement of specific science concepts are continuing in an effort not only to determine the most appropriate grade in which to introduce the concept with a specified degree of efficiency in learning, but also to gain an understanding of the general type of concept appropriate for specific grade levels. That is, are there limitations as to the type of concept, such as classificational, correlational, or theoretical, appropriate at certain age levels? Such questions still remain unanswered.

III
PROCEDURE

INTRODUCTION

To understand and appreciate living things implies some knowledge of a series of fundamental concepts of the living cell. Among these are concepts pertaining to structure, function, structure-function interrelationships, differentiation of cells in multicellular organisms, and cell reproduction with all of its implications. Each of these can be further subdivided into more specific subconcepts for emphasis. For example, one can consider the gross structure of the cell as viewed with the standard light microscope or one can proceed to analyze the structure by utilizing the electron microscope. Beyond this lies the area of molecular structure which is beyond the range of the electron microscope.

The aforementioned is only one example of the breadth of the conceptual scheme "the biological cell." The problem encountered in planning educational experiences aimed at the understanding and appreciation of living things at the elementary school level is one of limiting the scope of the concepts that become the content. Decisions must be made relative to the depth of understanding of the total scheme desired at a given maturity level. The first step in approaching this problem is one of subjectively selecting concepts for presentation at the elementary school level.

CONCEPT SELECTION

The selection of the concepts to be included as the variables in the experiment involved several steps:

1. The determination of the concepts related to "the biological cell" included within present elementary school science programs. This was accomplished through the analysis of 10 series of elementary science textbooks.
2. The determination of the composition of the conceptual scheme "the biological cell" in terms of concepts included.
   A. Lists and sequences of concepts were prepared through the use of:
      1. 16 high school biology textbooks.
      2. 10 college general biology textbooks (including botany and zoology textbooks).
      3. 2 cytology textbooks.
   B. The ordered sequence of concepts was submitted to a group of 8 science educators knowledgeable in biology.
3. The planning of lessons for the teaching of these concepts.
4. The development of a pilot study which proceeded as follows:
   A. The population included in the pilot study consisted of six pupils from a third grade and six pupils from a second grade in the Waunakee (Wis.) Elementary School.
   B. The procedure was of a clinical nature in which each instructional and test period involved a maximum of two pupils.
   C. The testing procedure was largely of the subjective oral variety.

As a result of the pilot study the concepts were slightly reordered and the lessons were revised and modified. Lessons are available in Practical Paper No. 2 of the Center (Stauss, 1967).

CONCEPT TEACHING

The final sequence of the lessons was determined by the sequence of the concepts selected and each concept was the basis for one day's instruction. Teaching was carried on for three weeks, Mondays through Thursdays. The evaluation of the lesson was conducted on the following day; testing was conducted on Tuesdays through Fridays during the three weeks.

Materials and procedures utilized were as follows:

1. Instructional materials consisted of: microscope; prepared microscope slides; prepared 2 x 2 slides of photomicrographs, diagramatic drawings, pictures, new or scientific terms, rock sections, and sections of metallic alloys; and film loops and the associated hardware for their use (Stauss, 1967).
2. All instructional and testing periods were conducted by the same qualified teacher.
3. Instructional procedures during the experimental period involved the technique of one teacher to a classroom; verbal presentation was supplemented by other instructional materials (Stauss, 1967).

EVALUATION

The level of achievement of the individual pupil was determined by his responses to items included in paper and pencil objective tests of the multiple choice multiple response type. In order to determine achievement concept by concept it was necessary to develop separate instruments for each of the concepts in the study.

The items in the tests were designed in accord with the *Taxonomy of Educational Objectives* by Bloom (1956) and further illustrated by Hedges (1966). The following decisions were made with reference to the tests.

1. Questions were to be of three types:
   A. Knowledge—demanded recall of specific information.
   B. Comprehension—demanded demonstration of capacity to generalize from specific items of fact, to cite fact in support of stated generalizations, to interpret or analyze a generalization, to restate the generalization in other terminology and to solve a problem involving the use of the generalization when given the generalization.
   C. Application—to apply concepts to new situations, previously outside of the experience of the pupil, without assistance.
2. There were to be equal numbers of each of the three types of questions on each of the concept tests. All tests included 36 items; 12 of each type for each concept.
3. Because of reading difficulties in several of the lower grade classes all tests were orally as well as visually presented to the pupils; pupils were encouraged to read along on their individual test copies as the teacher read to the class. Repetitions of reading individual items were carried out without concern for time; however, once a section of the test was completed return to that portion was not permitted. This was necessary because of the use of materials as clues, described in earlier parts of the test, on later parts. (Test copies and reliabilities are found in Stauss, 1967.)

POPULATION SELECTION

The selection of the school system from which to draw the experimental sample for this study was based upon one criterion: The system should be heterogeneous with reference to the socioeconomic background of the pupils. To be avoided were geographic and social areas in which the population was predominantly rural or industrial or, at the other extreme, composed of families engaged in government or university activities or jobs requiring a high level of academic training such that the home atmosphere would be unduly influenced. The school system selected offered a broad cross-section in which all of the above mentioned backgrounds were represented, thus giving a mixed population for the study.

The community selected, Verona, Wisconsin, has one public elementary school. Attending this school are students from the village as well as the surrounding rural areas.

SAMPLE SELECTION

The sample to be taught consisted of the pupils in one classroom at each grade level, two through six, selected from three classes each for Grades 2 and 3, and two each for Grades 4-6.

Pupil assignment to the individual classrooms within each grade at the beginning of the school year was random within grade levels, thus each group was assumed to be heterogeneous.

The selection of the specific classrooms for inclusion in the study was made by the school administrator on the basis of unit activities in nonscience areas already in progress, as well as the teacher's willingness to have her class used in the study. The selection of a particular class within a given grade produced no unusual situations which might affect the results of the study in an adverse manner.

Pupils whose scores were to be included in the analysis of the data were required to have been present for all instructional and testing periods. The minimum number of pupils considered acceptable for the study in any given classroom was 12. The minimum number of pupils retained in any class was 20. Where the number of pupils completing the entire instructional and testing sequence exceeded 20 in a given class, the number of pupils was reduced by random exclusion methods.

ANALYSIS OF THE DATA

The test scores for each lesson were analyzed by using a One-way Analysis of Variance program for the CDC computer at the University of Wisconsin Computing Center. An alpha of 0.05 was chosen for the analysis. Each subset of questions (knowledge, comprehension and application) from the test for each concept was analyzed in this manner. Newman-Keuls post-hoc tests were conducted to determine the location of significant differences revealed by the analysis of variance.

Correlations between concept test scores and the variables of age within a grade and IQ were calculated employing the REGEL program written by William Jaffarian for the CDC 3600 computer at the University of Wisconsin Computing Center. With $\alpha = 0.05$, for a two-tailed test, and 18 degrees of freedom, the tabled value of the correlation coefficient which would be regarded as significant is ± 0.444. All coefficients calculated were compared with this critical value to determine significance.

The determination of whether the class mean scores on the concept tests were significantly higher than those which could be achieved by random guessing was accomplished by the comparisons of the mean scores achieved by the classes with the mean of the distribution of means of all possible random samples from a theoretical distribution of random guessing scores. The formula

$$z_{.95} = \frac{\bar{X} - \mu_C}{\sigma_C / \sqrt{N}}$$

was utilized (based on the formula for the standard score for means, Walker and Lev, 1958), where μ_C is the mean of the distribution of means of all possible random samples from a theoretical distribution of random guessing scores, σ_C is the standard deviation of the theoretical distribution of means of random guessing scores, $z_{.95}$ is the standard score for means with confidence coefficient 0.95 and $\bar{X}$ is the critical value above which a class mean must fall to be significantly higher than the guessing mean. (Calculations of μ_C and σ_C based on formulae in Gulliksen, 1950.)

A final analysis of the data involved the determination, for each concept, of the number and percent of subjects in each class achieving a score of 65% or higher of the maximum attainable score at each level of understanding on the test for the concept.

CRITERIA FOR MINIMAL ACCEPTABLE ACHIEVEMENT

In order for achievement, with regard to a concept, to be considered satisfactory at a particular grade level, two criteria had to be satisfied:

1. The mean scores on the concept tests had to be significantly higher than a postulated guessing score.
2. A minimum of 50% of the class had to score 65% or higher of the maximum attainable score.

IV
RESULTS

INTRODUCTION

The results of this investigation are presented in two sections: (1) selected concepts, their order and classification, and (2) test results and analyses. The results and the analyses of the results will be described and discussed for each level of understanding for each concept test.

SELECTED CONCEPTS, THEIR ORDER AND CLASSIFICATION

The series of concepts within the conceptual scheme the biological cell selected as the content for instruction in this study, their order of presentation, and their classification are as follows:

1. Cells are parts of living things and living things only (Classificational).
2. Cells have a basic structure (Classificational).
3. The parts of cells have specific functions (Correlational).
4. Plant cells differ in structure depending upon their function (Correlational).
5. Animal cells differ in structure depending upon their function (Correlational).
6. The activities associated with life are carried on in the cell (Correlational).
7. Organisms differ in size depending upon the number of cells possessed, not the cell size (Correlational).
8. Cells come from previously existing cells as a result of the process of division (Classificational).
9. DNA is the important molecule concerned with regulation of cell activities (Theoretical).
10. DNA replicates itself and also serves as a template for RNA formation involved in regulation of cell activities (Theoretical).
11. Cells cannot grow to indefinite size (Correlational).

TEST RESULTS AND ANALYSES

Each pupil at each grade level received identical tests consisting of 36 questions related to each concept. The questions were evenly divided among the three taxonomic types: knowledge, comprehension, and application. Since there were 12 questions of each taxonomic type for each concept, the highest score attainable on any subset of questions was 12.

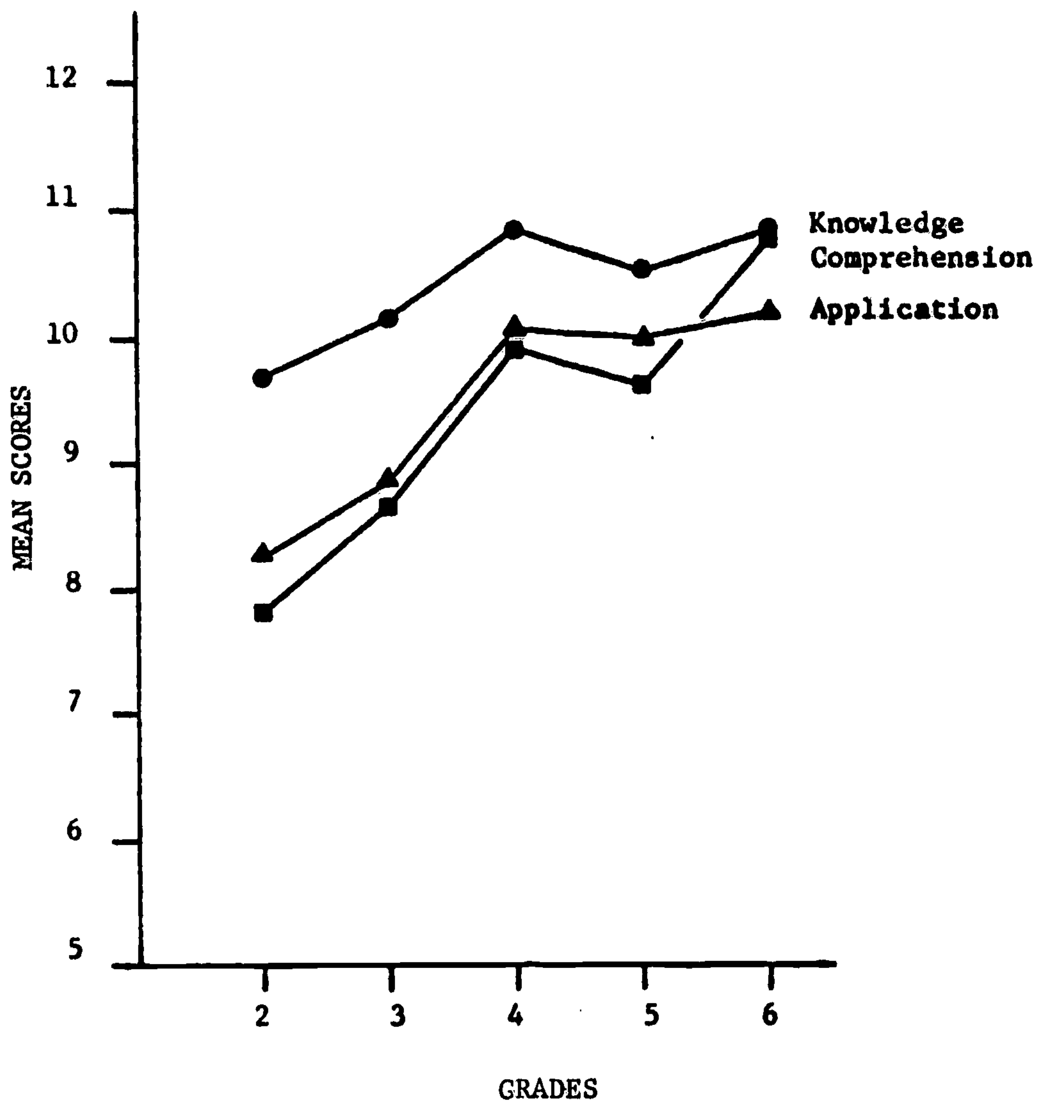
Concept One—Cells are part of living things and living things only

I. It is noted from Table 1 that the mean scores, at all grade levels, were consistently higher at the ***knowledge*** level than at either the ***comprehension*** or ***application*** levels. With minor variations the increase in achievement at the three levels of understanding from grade to grade is almost parallel. Graph I of the mean scores over all grades and levels of understanding reveals this parallelism.

Table 1. Concept 1. Mean test scores according to grade level and level of understanding

	Levels of Understanding		
Grade	K	C	A
2	9.70	7.80	8.25
3	10.15	8.70	8.85
4	10.85	9.90	10.10
5	10.55	9.60	10.00
6	10.85	10.80	10.20

Possible scores: K–Knowledge, C–Comprehension, and A–Application —12 each.



Graph I. Mean scores vs. grade level, concept 1

II. The following results are noted when the three taxonomic levels of understanding are considered separately.

A. Knowledge

No significant differences exist among the mean scores earned by pupils from different grades (Table 2).

B. Comprehension

1. Significant differences exist among the mean scores earned by pupils from different grades (Table 3).
2. The mean scores for the fourth and sixth grades are found to be significantly higher than that of the second grade; the mean score of the sixth grade is significantly higher than that of the third grade (Tables 4 and 5).

C. Application

1. Significant differences exist among the mean scores earned by pupils from different grades (Table 6).
2. The mean scores of Grades 4, 5, and 6 are significantly higher than those of Grades 2 and 3 (Tables 7 and 8).

Table 2. Concept 1. Knowledge. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	4.890	1.347	2.48
Within	95	3.629		
Total	99			

Table 3. Concept 1. Comprehension. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	26.460	4.266	2.48
Within	95	6.202		
Total	99			

Table 4. Concept 1. Comprehension. Differences between mean test scores by grade level

Grade	Means	2 7.80	3 8.70	5 9.60	4 9.90	6 10.80
2	7.80	0	.90	1.80	2.10*	3.00*
3	8.70		0	.90	1.20	2.10*
5	9.60			0	.30	1.20
4	9.90				0	.90
6	10.80					0

*$p < .05$ (groups listed by rank order)

Table 5. Concept 1. Comprehension. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}(r, 95)$	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	1.565	1.882	2.066	2.194

Table 6. Concept 1. Application. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	15.415	6.331	2.48
Within	95	2.435		
Total	99			

Table 7. Concept 1. Application. Differences between mean test scores by grade level

Grade	Means	2 8.25	3 8.85	5 10.00	4 10.10	6 10.20
2	8.25	0	.60	1.75*	1.85*	1.95*
3	8.85		0	1.15*	1.25*	1.35*
5	10.00			0	.10	.20
4	10.10				0	.10
6	10.20					0

*$p < .05$ (groups listed by rank order)

III. Comparisons of class mean scores with a critical guessing value (Table 9) reveal that all concept test mean scores at all levels of understanding exceed the guessing value.

IV. The achievement level of 50% of a class scoring 65% or higher is attained or surpassed by all classes at all levels of understanding (Table 10).

V. Comparisons of the correlation coefficients (Table 11) with the critical value for significance reveal that:

A. the relationships between concept test scores and the ages of the pupils within a grade are not significant, and

B. the relationships between concept test scores and IQ which are significant are those at:

1. Grade 2, the knowledge level,
2. Grades 4 and 5, all levels of understanding, and
3. Grade 6, the knowledge and application levels.

Table 8. Concept 1. Application. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}(r, 95)$	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	0.980	1.179	1.294	1.374

Table 9. Concept 1. Comparison of mean test scores by class and level of understanding with critical guessing score

Grades	Levels of Understanding		
	Knowledge	Comprehension	Application
2	9.70*	7.80*	8.25*
3	10.15*	8.70*	8.85*
4	10.85*	9.90*	10.10*
5	10.55*	9.60*	10.00*
6	10.85*	10.80*	10.20*

*Mean scores significantly greater than guessing.
Critical value = 6.63

Table 10. Concept 1. Number and percent of pupils earning scores equal to or greater than 65% according to grade and level of understanding

	LEVELS OF UNDERSTANDING					
	Knowledge		Comprehension		Application	
Grade	No. of pupils scoring 65% or higher	Percent of class	No. of pupils scoring 65% of higher	Percent of class	No. of pupils scoring 65% or higher	Percent of class
2	18	90	12	60	14	70
3	17	85	15	75	17	85
4	19	95	18	90	19	95
5	18	90	16	80	19	95
6	19	95	19	95	20	100

Number of students per class = 20.

Table 11. Concept 1. Relationship between individual test scores and selected variables according to grade level

Grade	Variable	Knowledge	Comprehension	Application
2	Age	-0.239	0.307	0.050
	IQ	0.526*	0.059	-0.174
3	Age	-0.238	0.305	0.139
	IQ	0.434	0.233	0.195
4	Age	-0.224	0.120	0.037
	IQ	0.517*	0.689*	0.614*
5	Age	0.066	0.007	0.037
	IQ	0.526*	0.691*	0.517*
6	Age	-0.177	0.187	0.209
	IQ	0.502*	0.409	0.593*

*Correlation coefficients significant at alpha = .05

Concept Two —Cells have a basic structure

I. Table 12 reveals that the mean scores, for all grade levels, were consistently higher on the *knowledge* type questions than on either the *comprehension* or *application* types. Little difference is noted between the achievement of the second and third grade pupils. The mean scores earned by the fourth-grade pupils exceeded those of the fifth grade at all levels of understanding and those from Grade 6 at the knowledge and comprehension levels. These relationships are more evident in Graph II.

II. The following results are noted when the three taxonomic levels of understanding are considered separately.

A. Knowledge

1. Significant differences exist among the mean scores earned by pupils from different grades (Table 13).
2. The mean scores of the fourth- and sixth-grade classes are significantly higher than those of the second- and third-grade classes (Tables 14 and 15).

Table 12. Concept 2. Mean test scores according to grade level and level of understanding

Grade	Levels of Understanding K	C	A
2	7.75	5.70	6.20
3	7.80	6.25	5.70
4	9.35	7.20	6.95
5	8.70	6.65	6.85
6	9.15	6.65	7.95

Possible scores: K—Knowledge, C—Comprehension, and A—Application —12 each.

Table 13. Concept 2. Knowledge. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	11.125	4.755	2.48
Within	95	2.339		
Total	99			

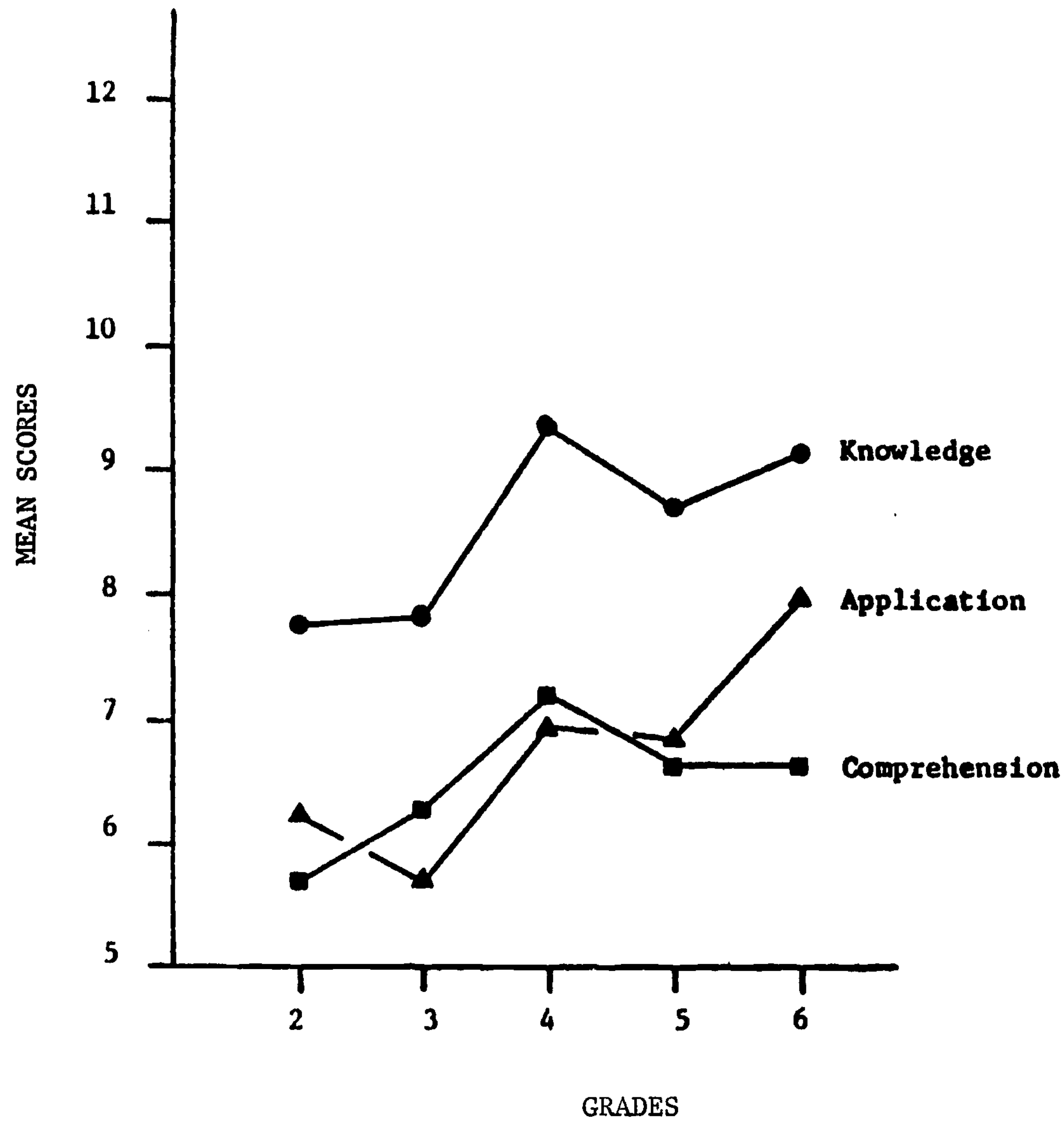
Table 14. Concept 2. Knowledge. Differences between mean test scores by grade level

Grade	Means	2 7.75	3 7.80	5 8.70	6 9.15	4 9.35
2	7.75	0	0.05	.95	1.40*	1.60*
3	7.80		0	.90	1.35*	1.55*
5	8.70			0	.45	.65
6	9.15				0	.20
4	9.35					0

*$p < .05$ (groups listed by rank order)

Table 15. Concept 2. Knowledge. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}(r, 95)$	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	0.961	1.156	1.268	1.347



Graph II. Mean scores vs. grade level, concept 2

B. Comprehension
No significant differences exist among the mean scores of the classes (Table 16).

C. Application
1. Significant differences exist among the mean scores attained by the classes (Table 17).

Table 16. Concept 2. Comprehension. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	6.185	1.882	2.48
Within	95	3.287		
Total	99			

Table 17. Concept 2. Application. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	14.465	3.304	2.48
Within	95	4.377		
Total	99			

2. The mean score earned by the sixth-grade class is significantly higher than the mean scores earned by the second- and third-grade classes (Tables 18 and 19).

III. Comparisons of class mean scores with a critical guessing value (Table 20) disclose that:
   A. the mean scores of all grade groups, at the knowledge level of understanding, are significantly different from guessing, and
   B. the mean scores for Grades 4, 5, and 6 exceed the critical value for guessing at the comprehension and application levels.

IV. The level of achievement of 50% of a class scoring 65% or higher (Table 21), is achieved or exceeded by:
   A. all classes at the knowledge level of understanding,
   B. no class at the comprehension level, and
   C. the fourth- and sixth-grade classes at the application level.

V. Comparisons of the correlation coefficients (Table 22) with the critical value for significance reveal that:
   A. the relationships between concept test scores and the ages of the pupils within a grade are not significant, except for Grade 6 at the knowledge level, and
   B. the relationships between concept test scores and IQ which are significant are those at:
      1. Grade 4, the comprehension and application levels,
      2. Grade 5, all levels of understanding, and
      3. Grade 6, the application level.

Table 18. Concept 2. Application. Differences between mean test scores by grade level

Grade	Means	3 5.70	2 6.20	5 6.85	4 6.95	6 7.95
3	5.70	0	.50	1.15	1.25	2.25*
2	6.20		0	.65	.75	1.75*
5	6.85			0	.10	1.10
4	6.95				0	1.00
6	7.95					0

*$p < .05$ (groups listed by rank order)

Table 19. Concept 2. Application. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}(r, 95)$	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	1.314	1.581	1.735	1.843

Table 20. Concept 2. Comparison of mean test scores by class and level of understanding with critical guessing score

Grade	Levels of Understanding		
	Knowledge	Comprehension	Application
2	7.75*	5.70	6.20
3	7.80*	6.25	5.70
4	9.35*	7.20*	6.95*
5	8.70*	6.65*	6.85*
6	9.15*	6.65*	7.95*

*Mean scores significantly greater than guessing. Critical value = 6.63

Table 21. Concept 2. Number and percent of pupils earning scores equal to or greater than 65% according to grade and level of understanding

	LEVELS OF UNDERSTANDING					
	Knowledge		Comprehension		Application	
Grade	No. of pupils scoring 65% or higher	Percent of class	No. of pupils scoring 65% or higher	Percent of class	No. of pupils scoring 65% or higher	Percent of class
2	12	60	2	10	4	20
3	13	65	3	15	3	15
4	17	85	9	45	10	50
5	17	85	5	25	7	35
6	18	90	6	30	11	55

Number of students per class = 20.

Table 22. Concept 2. Relationship between individual test scores and selected variables according to grade level

Grade	Variable	Knowledge	Comprehension	Application
2	Age	-0.246	-0.165	-0.003
	IQ	0.366	-0.014	-0.004
3	Age	-0.061	0.174	0.033
	IQ	0.116	0.030	-0.168
4	Age	0.310	-0.164	0.138
	IQ	0.298	0.465*	0.556*
5	Age	-0.175	-0.176	-0.142
	IQ	0.505*	0.453*	0.464*
6	Age	0.541*	-0.267	-0.023
	IQ	0.089	0.170	0.561*

*Correlation coefficients significant at alpha = .05

Concept Three —The parts of cells have specific function

I. An examination of the mean scores included in Table 23 and Graph III reveals that:

A. the pupils in Grades 3-6 scored highest on the comprehension type questions,

B. it was only in Grade 2 that the mean score for the knowledge type questions was higher than for comprehension,

C. the mean scores on application questions were noticeably lower than those on the comprehension subset at all grade levels, and

D. in Grades 2-4, the mean scores on the application type questions were lower than those on the knowledge type, while at Grades 5 and 6 they exceeded the mean scores on the knowledge type.

II. The following results are noted when the three taxonomic levels of understanding are considered separately.

A. Knowledge

1. There are significant differences among the mean scores earned by the several grades (Table 24).
2. Post-hoc tests on the differences between members of pairs of mean scores fail to locate any significant differences (Tables 25 and 26).

Table 23. Concept 3. Mean test scores according to grade level and level of understanding

Grade	Levels of Understanding K	C	A
2	8.45	8.30	6.85
3	8.45	9.20	6.75
4	9.75	10.75	8.75
5	8.25	10.00	8.60
6	9.60	11.25	10.00

Possible score: K—Knowledge, C—Comprehension, and A—Application —12 each.

Table 24. Concept 3. Knowledge. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	10.200	2.783	2.48
Within	95	3.665		
Total	99			

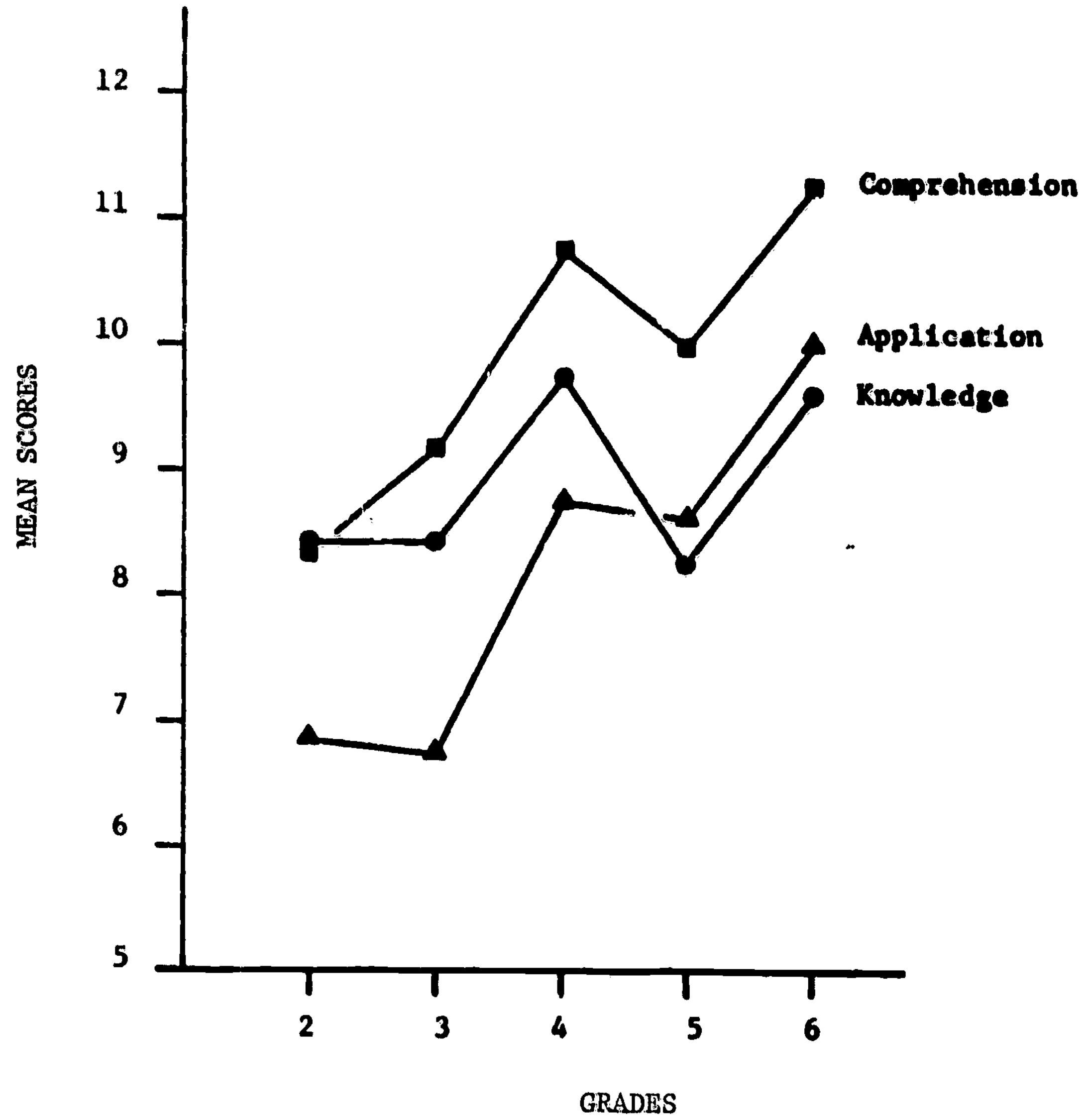
Table 25. Concept 3. Knowledge. Differences between mean test scores by grade level

Grade	Means	5 8.25	2 8.45	3 8.45	6 9.60	4 9.75
5	8.25	0	.20	.20	1.35	1.50
2	8.45		0	0	1.15	1.30
3	8.45			0	1.15	1.30
6	9.60				0	.15
4	9.75					0

*$p < .05$ (groups listed by rank order

Table 26. Concept 3. Knowledge. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}(r, 95)$	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	1.203	1.447	1.588	1.686



Graph III. Mean scores vs. grade level, concept 3

B. Comprehension
1. Significant differences exist among the mean scores earned by pupils from different grades (Table 27).
2. The mean scores earned by the fourth-, fifth-, and sixth-grade classes are significantly higher than the mean score of Grade 2; those of Grades 4 and 6 are significantly higher than that of Grade 3 (Tables 28 and 29).

Table 27. Concept 3. Comprehension. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	28.025	9.345	2.48
Within	95	2.999		
Total	99			

Table 28. Concept 3. Comprehension. Differences between mean test scores by grade level

Grades		2	3	5	4	6
	Means	8.30	9.20	10.00	10.75	11.25
2	8.30	0	.90	1.70*	2.45*	2.95*
3	9.20		0	.80	1.55*	2.05*
5	10.00			0	.75	1.25
4	10.75				0	.50
6	11.25					0

*$p < .05$ (groups listed by rank order)

C. Application
   1. Significant differences exist among the mean scores earned by the classes (Table 30).
   2. The mean scores attained by Grades 4, 5, and 6 are significantly higher than those of Grades 2 and 3 (Tables 31 and 32).

III. Comparisons of class mean scores with a critical guessing value (Table 33) reveal that all concept test mean scores at all levels of understanding are significantly higher than guessing.

IV. The achievement level of 50% of a class scoring 65% or higher (Table 34) is attained or surpassed by:
   A. all classes at the knowledge and comprehension levels of understanding, and
   B. Grades 4-6 at the application level.

V. Comparisons of the correlation coefficients (Table 35) with the critical value for significance reveal that:
   A. the relationships between concept test scores and the ages of the pupils within a grade are not significant, and
   B. the relationships between concept test scores and IQ which are significant are those at Grades 4 and 5 at the comprehension level of understanding.

Table 29. Concept 3. Comprehension. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}(r, 95)$	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	1.088	1.308	1.436	1.525

Table 30. Concept 3. Application. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	38.135	10.096	2.48
Within	95	3.777		
Total	99			

Table 31. Concept 3. Application. Differences between mean test scores by grade level

Grade		3	2	5	4	6
	Means	6.75	6.85	8.60	8.75	10.00
3	6.75	0	.10	1.85*	2.00*	3.25*
2	6.85		0	1.75*	1.90*	3.15*
5	8.60			0	.15	1.40
4	8.75				0	1.25
6	10.00					0

*$p < .05$ (groups listed by rank order)

Table 32. Concept 3. Application. Critical values for Newman-Keuls Test

r	2	3	4	5
$q_{.95}(r, 95)$	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	1.221	1.469	1.612	1.712

Table 33. Concept 3. Comparison of mean test scores by class and level of understanding with critical guessing score

Grade	Levels of Understanding		
	Knowledge	Comprehension	Application
2	8.45*	8.30*	6.85*
3	8.45*	9.20*	6.75*
4	9.75*	10.75*	8.75*
5	8.25*	10.00*	8.60*
6	9.60*	11.25*	10.00*

*Mean scores significantly greater than guessing.
Critical value = 6.63

Table 34. Concept 3. Number and percent of pupils earning scores equal to or greater than 65% according to grade and level of understanding

	LEVEL OF UNDERSTANDING					
	Knowledge		Comprehension		Application	
Grade	No. of pupils scoring 65% or higher	Percent of class	No. of pupils scoring 65% or higher	Percent of class	No. of pupils scoring 65% or higher	Percent of class
2	14	70	13	65	8	40
3	14	70	15	75	6	30
4	19	95	20	100	16	80
5	14	70	19	95	14	70
6	17	85	20	100	17	85

Number of students per class = 20.

Table 35. Concept 3. Relationship between individual test scores and selected variables according to grade level

Grade	Variable	Knowledge	Comprehension	Application
2	Age	0.265	0.292	-0.168
	IQ	-0.025	0.095	0.242
3	Age	0.125	-0.081	0.011
	IQ	0.294	0.039	0.310
4	Age	0.032	0.070	0.126
	IQ	0.216	0.661*	0.399
5	Age	-0.324	-0.139	-0.154
	IQ	0.046	0.635*	0.429
6	Age	0.182	0.059	0.415
	IQ	0.283	0.121	0.425

*Correlation coefficients significant at alpha = .05

Concept Four—Plant cells differ in structure depending upon their function

I. It is noted from Table 36 and Graph IV that the mean scores at all grade levels are consistently higher at the *knowledge* level than at either the *comprehension* or *application* levels of understanding and that there is a general increase in mean scores at all levels of understanding as one moves from Grade 2 to Grade 6.

II. The following results are noted when the three taxonomic levels of understanding are considered separately.

A. Knowledge

1. Significant differences exist among the mean scores earned by the pupils from different grades (Table 37).
2. The mean scores from Grades 3-6 are significantly higher than that for Grade 2 (Tables 38 and 39).

B. Comprehension

1. Significant differences exist among the mean scores attained by the classes (Table 40).
2. The mean scores for the third through sixth grades are significantly higher than that for the second grade and the mean score for Grade 6 is significantly higher than the mean score for Grade 3 (Tables 41 and 42).

Table 36. Concept 4. Mean test scores according to grade level and level of understanding

Grade	Levels of Understanding K	C	A
2	8.05	5.55	6.80
3	9.50	7.55	7.45
4	10.40	8.85	8.20
5	9.70	8.45	8.30
6	10.45	9.45	9.00

Possible scores: K–Knowledge, C–Comprehension, and A–Application —12 each.

Table 37. Concept 4. Knowledge. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	18.915	6.561	2.48
Within	95	2.883		
Total	99			

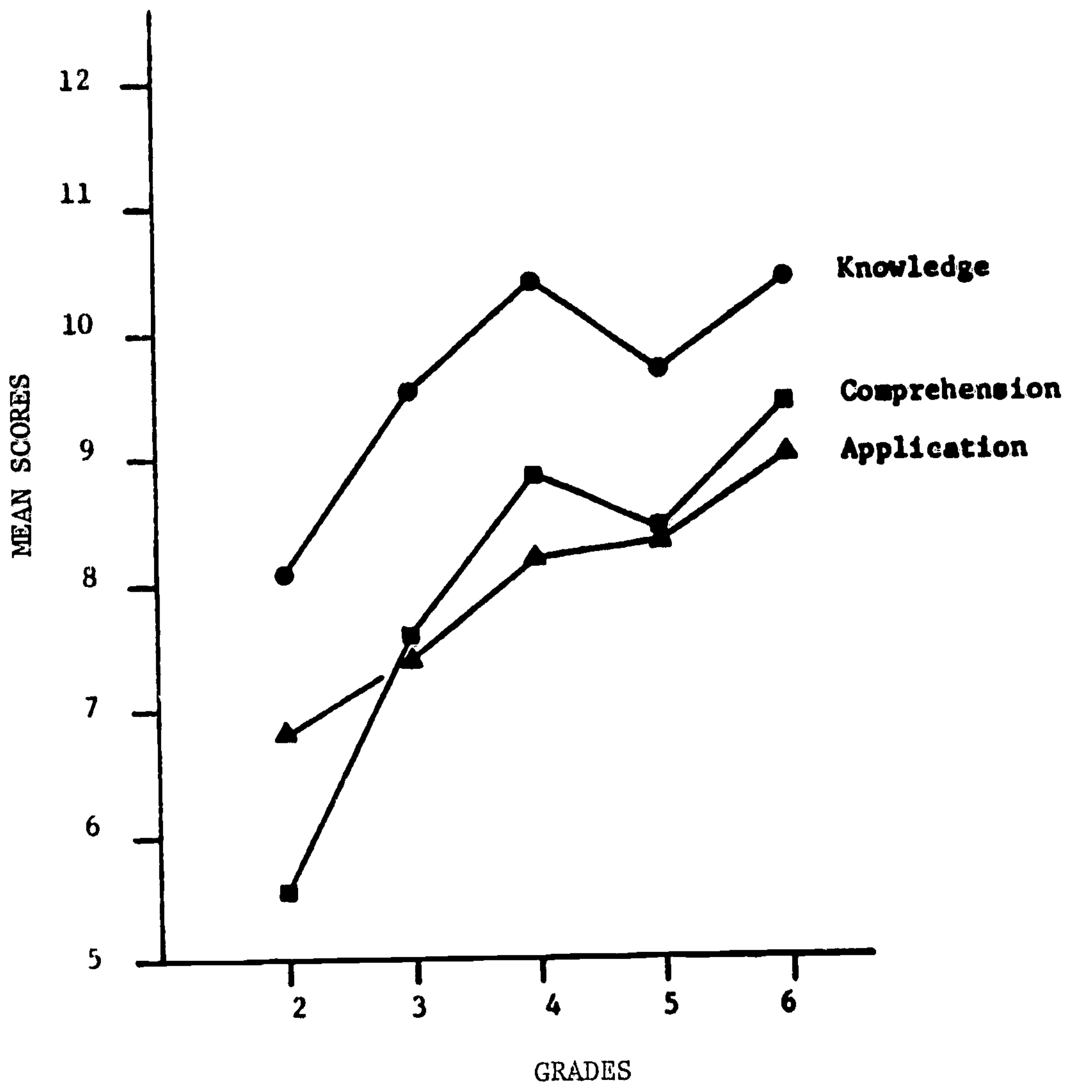
Table 38. Concept 4. Knowledge. Differences between mean test scores by grade level

Grade	Means	2 8.05	3 9.50	5 9.70	4 10.40	6 10.45
2	8.05	0	1.45*	1.65*	2.35*	2.40*
3	9.50		0	.20	.90	.95
5	9.70			0	.70	.75
4	10.40				0	.05
6	10.45					0

*p < .05 (groups listed by rank order)

Table 39. Concept 4. Knowledge. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}(r, 95)$	2.81	2.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	1.067	1.283	1.408	1.496



Graph IV. Mean scores vs. grade level, concept 4

Table 40. Concept 4. Comprehension. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	46.140	9.733	2.48
Within	95	4.741		
Total	99			

Table 41. Concept 4. Comprehension. Differences between mean test scores by grade level

Grade	Means	2 5.55	3 7.55	5 8.45	4 8.85	6 9.45
2	5.55	0	2.00*	2.90*	3.30*	3.90*
3	7.55		0	.90	1.30	1.90*
5	8.45			0	.40	1.00
4	8.85				0	.60
6	9.45					0

*$p < .05$ (groups listed by rank order)

Table 42. Concept 4. Comprehension. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}$ (r, 95)	2.81	3.38	3.71	3.94
$q_{.95}$ (r, 95) $\sqrt{\frac{MS_{error}}{n}}$	1.368	1.645	1.806	1.918

C. Application
1. Significant differences exist among the classes in terms of the mean scores earned (Table 43).
2. The mean score for the sixth-grade class is significantly higher than the mean score for the second-grade class (Tables 44 and 45).

III. Comparisons of the mean scores for all classes at all taxonomic levels of understanding with the critical value for random guessing (Table 46) reveal that:
A. at the knowledge and application levels, the mean scores of all grade groups exceed the critical guessing value, and
B. at the comprehension level, the mean scores for all classes except that for the second grade exceed the critical value.

IV. The achievement level of 50% of a class scoring 65% or higher (Table 47) is attained or surpassed by:
A. all classes at the knowledge level, and
B. the classes from Grades 3-6 at the comprehension and application levels of understanding.

V. Comparisons of the correlation coefficients (Table 48) with the critical value for significance reveal that:
A. the relationships between concept test scores and the ages of the pupils within a grade are not significant, and
B. the relationships between concept test scores and IQ which are significant are those at:
1. Grade 3, the comprehension level,
2. Grades 4 and 5, the application level, and
3. Grade 6, the comprehension and application levels of understanding.

Table 43. Concept 4. Application. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	14.300	2.995	2.48
Within	95	4.774		
Total	99			

Table 44. Concept 4. Application. Differences between mean test scores by grade level

Grade		2	3	4	5	6
	Means	6.80	7.45	8.20	8.30	9.00
2	6.80	0	.65	1.40	1.50	2.20*
3	7.45		0	.75	.85	1.55
4	8.20			0	.10	.80
5	8.30				0	.70
6	9.00					0

*p < .05 (groups listed by rank order)

Table 45. Concept 4. Application. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}(r, 95)$	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	1.373	1.651	1.812	1.925

Table 46. Concept 4. Comparison of mean test scores by class and level of understanding with critical guessing score

Grade	Levels of Understanding		
	Knowledge	Comprehension	Application
2	8.05*	5.55	6.80*
3	9.50*	7.55*	7.45*
4	10.40*	8.85*	8.20*
5	9.70*	8.45*	8.30*
6	10.45*	9.45*	9.00*

*Mean scores significantly greater than guessing.
Critical value = 6.63

Table 47. Concept 4. Number and percent of pupils earning scores equal to or greater than 65% according to grade and level of understanding

	LEVELS OF UNDERSTANDING					
	Knowledge		Comprehension		Application	
Grade	No. of pupils scoring 65% or higher	Percent of class	No. of pupils scoring 65% or higher	Percent of class	No. of pupils scoring 65% or higher	Percent of class
2	11	55	3	15	7	35
3	19	95	11	55	11	55
4	19	95	13	65	13	65
5	17	85	13	65	13	65
6	17	85	17	85	14	70

Number of students per class = 20.

Table 48. Concept 4. Relationship between individual test scores and selected variables according to grade level

Grade	Variable	Knowledge	Comprehension	Application
2	Age	0.285	0.019	-0.218
	IQ	-0.071	0.260	0.133
3	Age	0.224	-0.396	0.007
	IQ	-0.131	0.622*	-0.086
4	Age	0.183	0.158	0.137
	IQ	0.308	0.421	0.650*
5	Age	-0.317	-0.094	-0.165
	IQ	0.426	0.364	0.503*
6	Age	-0.024	0.164	-0.110
	IQ	0.422	0.515*	0.491*

*Correlation coefficients significant at alpha = .05

Concept Five—Animal cells differ in structure depending upon their function

I. It is noted from Table 49 and Graph V that:
   A. the mean scores at all grade levels were consistently higher at the *knowledge* level of understanding than at either the comprehension or application levels, and
   B. the mean scores for the *comprehension* and *application* type questions follow somewhat the same pattern as the knowledge mean scores, but at a somewhat lower level.

II. The following results are noted when the three taxonomic levels of understanding are considered separately.
   A. Knowledge
      1. Significant differences exist among the mean scores earned by the pupils from different grades (Table 50).
      2. The mean score for Grade 6 is found to be significantly higher than the mean scores for Grades 2, 3, 4, and 5 (Tables 51 and 52).
   B. Comprehension
      1. Significant differences exist among the mean scores attained by the classes (Table 53).
      2. The mean score for Grade 6 is significantly higher than those for Grades 2-5 (Tables 54 and 55).

Table 49. Concept 5. Mean test scores according to grade level and level of understanding

Grade	Levels of Understanding K	C	A
2	8.70	6.60	6.20
3	8.55	7.85	7.45
4	9.70	8.40	9.25
5	9.25	8.15	8.35
6	11.25	10.10	9.60

Possible scores: K–Knowledge, C–Comprehension, and A–Application —12 each.

Table 50. Concept 5. Knowledge. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	23.535	9.361	2.48
Within	95	2.514		
Total	99			

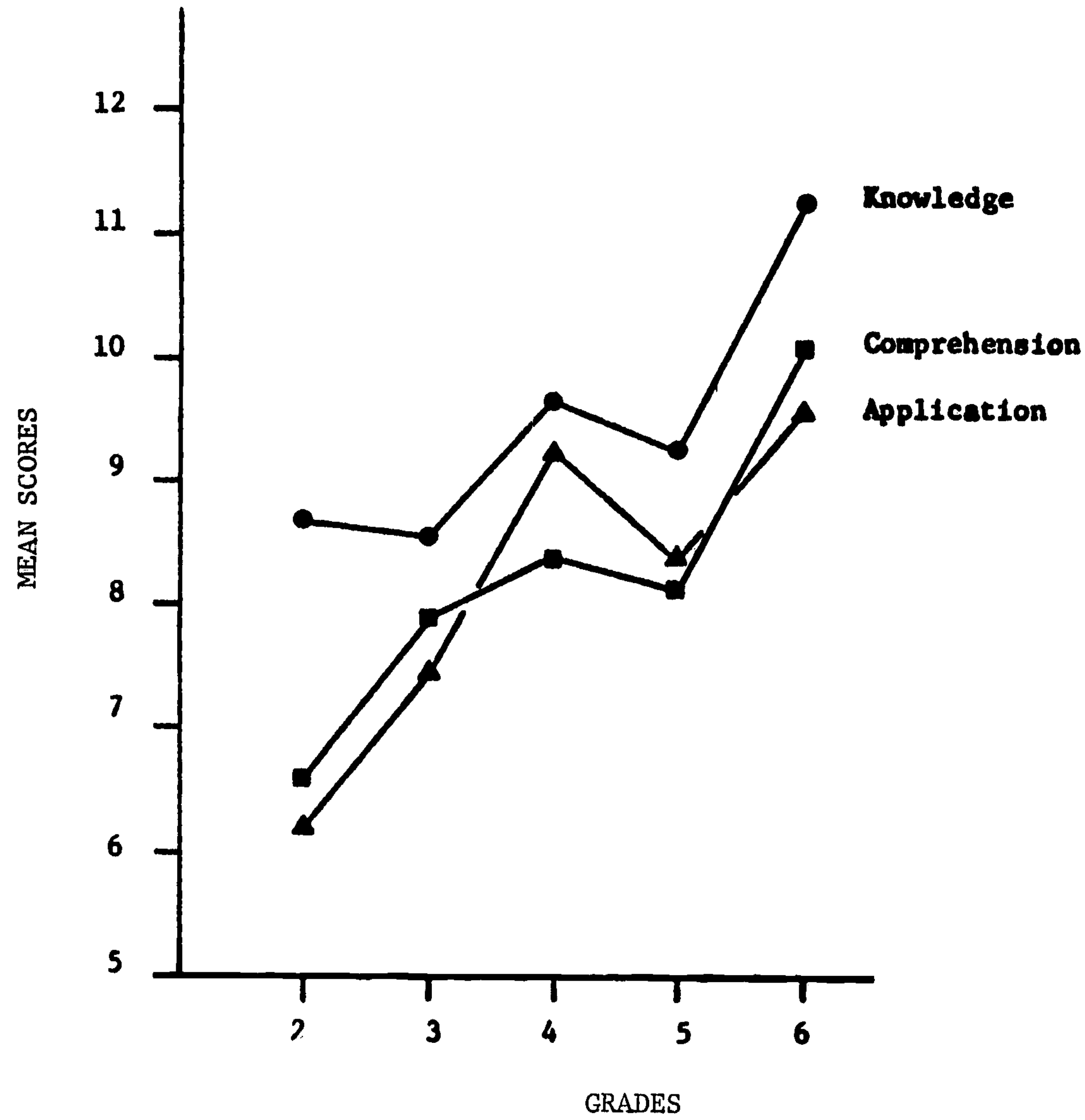
Table 51. Concept 5. Knowledge. Differences between mean test scores by grade level

Grade		3	2	5	4	6
	Means	8.55	8.70	9.25	9.70	11.25
3	8.55	0	.15	.70	1.15	2.70*
2	8.70		0	.55	1.00	2.55*
5	9.25			0	.45	2.00*
4	9.70				0	1.55*
6	11.25					0

*$p < .05$ (groups listed by rank order)

Table 52. Concept 5. Knowledge. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}(r, 95)$	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	0.996	1.198	1.315	1.397



Graph V. Mean scores vs. grade level, concept 5

Table 53. Concept 5. Comprehension. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	31.665	6.421	2.48
Within	95	4.932		
Total	99			

Table 54. Concept 5. Comprehension. Differences between mean test scores by grade level

Grade		2	3	5	4	6
	Means	6.60	7.85	8.15	8.40	10.10
2	6.60	0	1.25	1.55	1.80	3.50*
3	7.85		0	.30	.55	2.25*
5	8.15			0	.25	1.95*
4	8.40				0	1.70*
6	10.10					0

*p < .05 (groups listed by rank order)

Table 55. Concept 5. Comprehension. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}$ (r, 95)	2.81	3.38	3.71	3.94
$q_{.95}$ (r, 95) $\sqrt{\frac{MS_{error}}{n}}$	1.395	1.678	1.842	1.956

C. Application

1. The existence of significant differences among the mean scores of the classes is apparent (Table 56).
2. The mean scores earned by Grades 4-6 are significantly higher than the mean score for Grade 2; those for Grades 4 and 6 are significantly higher than the mean score of Grade 3 (Tables 57 and 58).

III. Comparisons of class mean scores with a critical guessing value (Table 59) disclose that:

A. all mean scores at the knowledge level are significantly greater than can be expected by random guessing, and
B. the mean scores for Grades 3-6 exceed the critical value for guessing at the comprehension and application levels of understanding.

IV. Table 60 shows that the achievement level of 50% of a class scoring 65% or higher is attained or exceeded:

A. by all grades at the knowledge level,
B. by Grades 3-6 at the comprehension level, and
C. by Grades 4-6 at the application level of understanding.

V. Comparisons of the correlation coefficients (Table 61) with the critical value for significance reveal that:

A. the relationships between concept test scores and the ages of the pupils within a grade are not significant, and
B. the relationships between concept test scores and IQ which are significant are those at:
   1. Grade 4, the comprehension and application levels,
   2. Grade 5, all levels of understanding, and
   3. Grade 6, the application level.

Table 56. Concept 5. Application. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	38.215	7.157	2.48
Within	95	5.339		
Total	99			

Table 57. Concept 5. Application. Differences between mean test scores by grade level

Grade		2	3	5	4	6
	Means	6.20	7.45	8.35	9.25	9.60
2	6.20	0	1.25	2.15*	3.05*	3.40*
3	7.45		0	.90	1.80*	2.15*
5	8.35			0	.90	1.25
4	9.25				0	.35
6	9.60					0

*$p < .05$ (groups listed by rank order)

Table 58. Concept 5. Application. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}(r, 95)$	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	1.452	1.746	1.917	2.035

GPO 807-639-4

Table 59. Concept 5. Comparison of mean test scores by class and level of understanding with critical guessing score

Grade	Levels of Understanding		
	Knowledge	Comprehension	Application
2	8.70*	6.60	6.20
3	8.55*	7.85*	7.45*
4	9.70*	8.40*	9.25*
5	9.25*	8.15*	8.35*
6	11.25*	10.10*	9.60*

*Mean scores significantly greater than guessing.
Critical value = 6.63

Table 60. Number and percent of pupils earning scores equal to or greater than 65% according to grade and level of understanding

	LEVELS OF UNDERSTANDING					
	Knowledge		Comprehension		Application	
Grade	No. of pupils scoring 65% or higher	Percent of class	No. of pupils scoring 65% or higher	Percent of class	No. of pupils scoring 65% or higher	Percent of class
2	15	75	5	25	5	25
3	15	75	11	55	8	40
4	19	95	13	65	15	75
5	15	75	12	60	12	60
6	20	100	18	90	15	75

Number of students per class = 20.

Table 61. Concept 5. Relationship between individual test scores and selected variables according to grade level

Grade	Variable	Knowledge	Comprehension	Application
2	Age	0.123	-0.015	-0.127
	IQ	0.137	0.237	0.383
3	Age	0.105	0.023	0.351
	IQ	0.198	-0.139	0.136
4	Age	-0.381	-0.097	-0.273
	IQ	0.408	0.630*	0.544*
5	Age	-0.273	-0.148	-0.075
	IQ	0.611*	0.555*	0.568*
6	Age	0.062	0.111	0.112
	IQ	0.169	0.190	0.602*

Correlation coefficients significant at alpha = .05

Concept Six—The activities associated with life are carried on in the cell

I. Reference to Table 62 and Graph VI reveals that except at the third and sixth grades, all mean scores attained on the *knowledge* type questions are exceeded by those attained on the *comprehension* and *application* types. The difference between mean scores at the *comprehension* and *application* levels remains relatively constant across Grades 4, 5, and 6.

II. The following results are noted when the three taxonomic levels of understanding are considered separately.

A. Knowledge
No significant differences exist among the mean scores earned by pupils from different grades (Table 63).

B. Comprehension
No significant differences exist among the mean scores earned by pupils from different grades (Table 64).

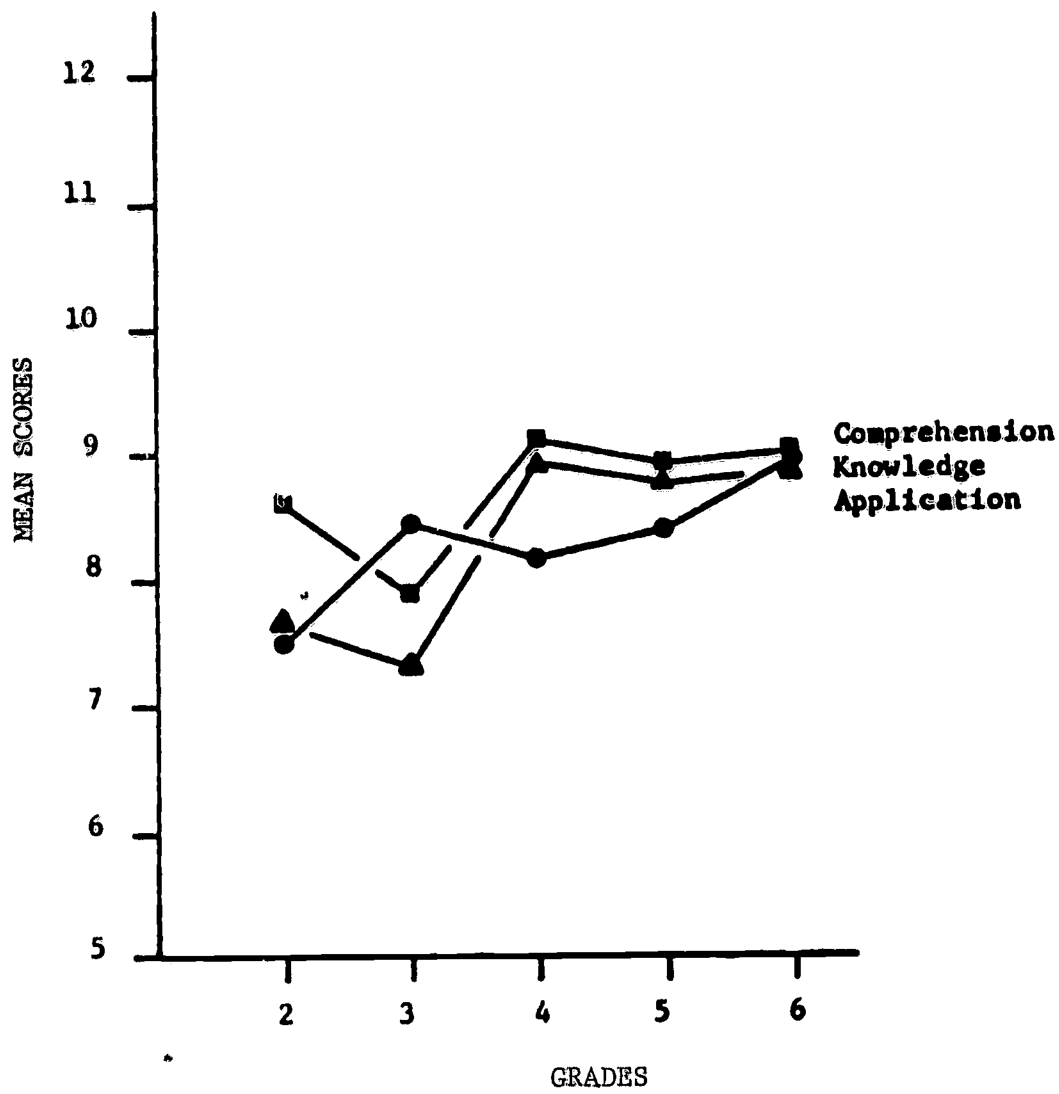
Table 62. Concept 6. Mean test scores according to grade level and level of understanding

Grade	Levels of Understanding		
	K	C	A
2	7.50	8.60	7.65
3	8.45	7.85	7.30
4	8.20	9.10	8.90
5	8.30	8.90	8.75
6	8.95	9.00	8.85

Possible scores: K–Knowledge, C–Comprehension, and A–Application —12 each.

Table 63. Concept 6. Knowledge. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	5.465	1.852	2.48
Within	95	2.951		
Total	99			



Graph VI. Mean scores vs. grade level, concept 6

Table 64. Concept 6. Comprehension. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	5.110	1.449	2.48
Within	95	3.526		
Total	99			

C. Application
   1. The analysis of variance indicates a significant difference among the mean scores of the classes (Table 65).
   2. Post-hoc tests on differences between members of pairs of mean scores fail to locate the significant differences (Tables 66 and 67).

III. Comparisons of class mean scores with a critical guessing value (Table 68) reveal that all concept test mean scores at all levels of understanding are significantly higher than guessing.

IV. The achievement level of 50% of a class scoring 65% or higher (Table 69) is attained or surpassed by:
   A. Grades 3-6 at the knowledge level, and
   B. all classes (Grades 2-6) at the comprehension and application levels.

V. Comparisons of the correlation coefficients (Table 70) with the critical value for significance reveal that:
   A. the relationships between concept test scores and the ages of the pupils within a grade are not significant, except for Grade 5 at the knowledge level, where a significant negative relationship exists, and
   B. the relationships between concept test scores and IQ which are significant are those at:
      1. Grade 4, the knowledge level,
      2. Grade 5, the knowledge and application levels, and
      3. Grade 6, the application level of understanding.

Table 65. Concept 6. Application. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	11.435	3.303	2.48
Within	95	3.462		
Total	99			

Table 66. Concept 6. Application. Differences between mean test scores by grade level

Grade		3	2	5	6	4
	Means	7.30	7.65	8.75	8.85	8.90
3	7.30	0	.35	1.45	1.55	1.60
2	7.65		0	1.10	1.20	1.25
5	8.75			0	.10	.15
6	8.85				0	.05
4	8.90					0

*$p < .05$ (groups listed by rank order)

Table 67. Concept 6. Application. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}(r, 95)$	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	1.169	1.406	1.543	1.639

Table 68. Concept 6. Comparison of mean test scores by class and level of understanding with critical guessing score

Grade	Levels of Understanding		
	Knowledge	Comprehension	Application
2	7.50*	8.60*	7.65*
3	8.45*	7.85*	7.30*
4	8.20*	9.10*	8.90*
5	8.30*	8.90*	8.75*
6	8.95*	9.00*	8.85*

*Mean scores significantly greater than guessing.
Critical value = 6.63

Table 69. Concept 6. Number and percent of pupils earning scores equal to or greater than 65% according to grade and level of understanding

	LEVELS OF UNDERSTANDING					
	Knowledge		Comprehension		Application	
Grade	No. of pupils scoring 65% or higher	Percent of class	No. of pupils scoring 65% or higher	Percent of class	No. of pupils scoring 65% or higher	Percent of class
2	9	45	14	70	13	65
3	15	75	10	50	11	55
4	13	65	18	90	15	75
5	13	65	16	80	16	80
6	18	90	17	85	17	85

Number of students per class = 20.

Table 70. Concept 6. Relationship between individual test scores and selected variables according to grade level

Grade	Variable	Knowledge	Comprehension	Application
2	Age	0.146	-0.009	-0.073
	IQ	-0.234	0.084	0.032
3	Age	0.170	-0.225	0.008
	IQ	-0.183	0.380	-0.006
4	Age	-0.158	0.111	0.037
	IQ	0.493*	-0.018	0.377
5	Age	-0.463*	-0.135	-0.247
	IQ	0.490*	-0.062	0.640*
6	Age	0.184	-0.317	0.241
	IQ	0.078	-0.054	0.492*

*Correlation coefficients significant at alpha = .05

Concept Seven —Organisms differ in size depending upon the number of cells possessed, not the cell size

I. Table 71 and Graph VII disclose that:

A. the mean scores attained at the *knowledge* and *comprehension* levels increase progressively from grade to grade; a trend which, with the exception of Grade 5, also exists for the *application* type questions, and

B. the difference between mean scores at the *knowledge* and *comprehension* levels remains relatively constant across Grades 2-5; a pattern which is also followed by the mean scores for the *application* level of understanding from Grades 2-4.

II. The following results are noted when the three taxonomic levels of understanding are considered separately.

A. Knowledge

1. Significant differences exist among the mean scores earned by pupils from different grades (Table 72).
2. The mean scores attained by Grades 5 and 6 are significantly higher than those attained by Grades 2 and 3 (Tables 73 and 74).

B. Comprehension

1. The analysis of variance discloses a significant difference among the mean scores of the classes (Table 75).
2. The mean score for Grade 6 is significantly higher than those for Grades 2-5; the mean score for Grade 5 is significantly higher than those for Grades 2 and 3 and that for Grade 4 is significantly higher than the mean score for Grade 2 (Tables 76 and 77).

Table 71. Concept 7. Mean test scores according to grade level and level of understanding

Grade	Levels of Understanding K	C	A
2	8.55	6.60	7.20
3	8.70	7.15	7.40
4	9.75	8.30	8.40
5	10.60	9.30	8.00
6	10.95	11.05	10.25

Possible scores: K–Knowledge, C–Comprehension, and A–Application —12 each.

Table 72. Concept 7. Knowledge. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	23.485	6.627	2.48
Within	95	3.544		
Total	99			

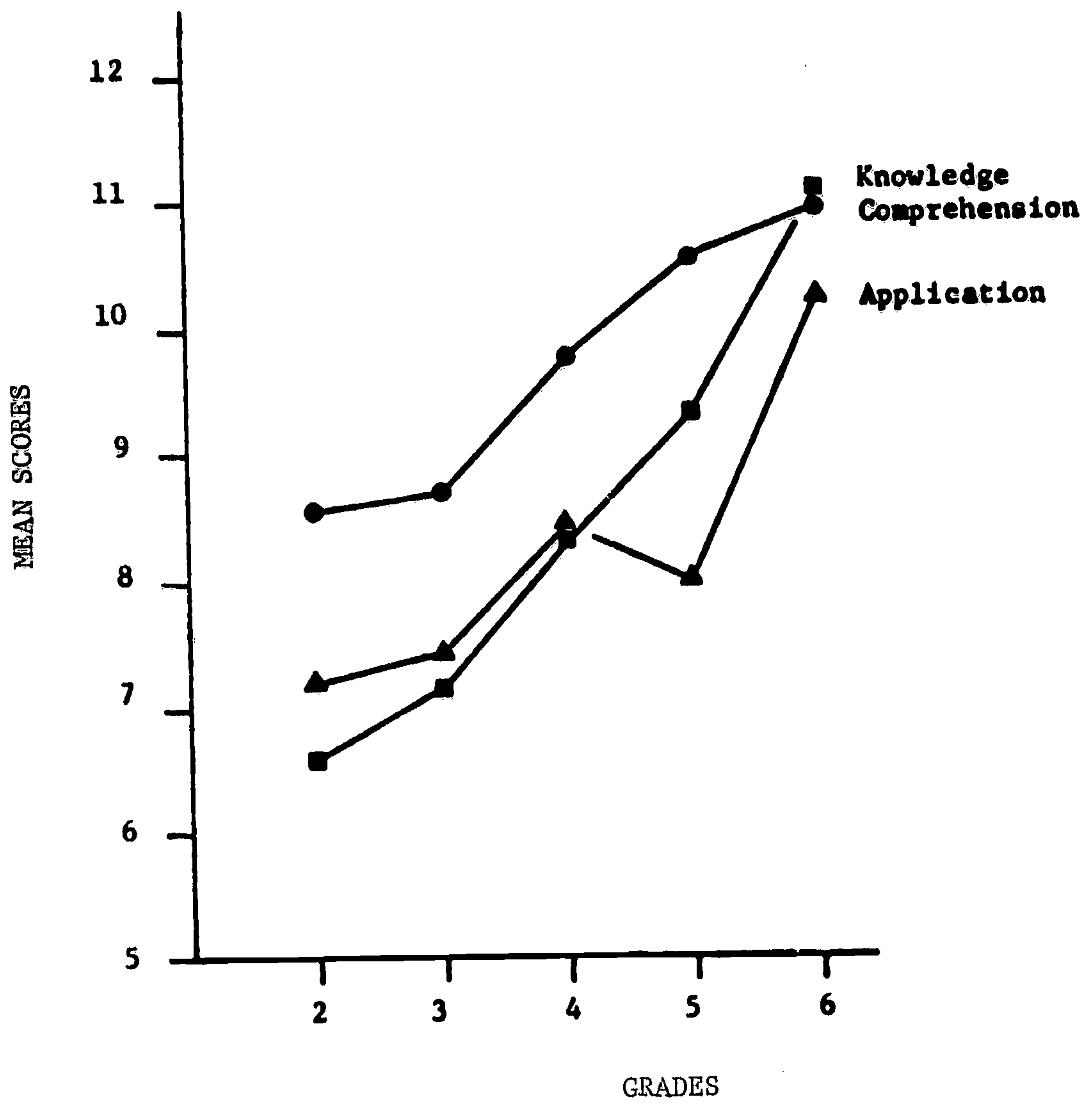
Table 73. Concept 7. Knowledge. Differences between mean test scores by grade level

Grade	Means	2 8.55	3 8.70	4 9.75	5 10.60	6 10.95
2	8.55	0	.15	1.20	2.05*	2.40*
3	8.70		0	1.05	1.90*	2.25*
4	9.75			0	.85	1.20
5	10.60				0	.35
6	10.95					0

*p < .05 (groups listed by rank order)

Table 74. Concept 7. Knowledge. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}(r, 95)$	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	1.183	1.423	1.562	1.658



Graph VII. Mean scores vs. grade level, concept 7

Table 75. Concept 7. Comprehension. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	63.065	13.472	2.48
Within	95	4.681		
Total	99			

Table 76. Concept 7. Comprehension. Differences between mean test scores by grade level

Grade		2	3	4	5	6
	Means	6.60	7.15	8.30	9.30	11.05
2	6.60	0	.55	1.70*	2.70*	4.45*
3	7.15		0	1.15	2.15*	3.90*
4	8.30			0	1.00	2.75*
5	9.30				0	1.75*
6	11.05					0

*$p < .05$ (groups listed by rank order)

Table 77. Concept 7. Comprehension. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}(r, 95)$	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	1.359	1.635	1.794	1.906

C. Application
   1. Significant differences exist among the classes in terms of mean scores earned (Table 78).
   2. The mean score for the sixth-grade class is significantly higher than the mean scores for Grades 2-5 (Tables 79 and 80).

III. Comparisons of class mean scores with a critical guessing value (Table 81) reveal that:
   A. all concept test mean scores at the knowledge and application levels of understanding exceed the guessing value, and
   B. at the comprehension level the mean scores for Grades 3-6 exceed the guessing value.

IV. The achievement level of 50% of a class scoring 65% or higher (Table 82) is attained or exceeded by:
   A. all grades at the knowledge level,
   B. Grades 4-6 at the comprehension level, and
   C. Grades 3-6 at the application level of understanding.

V. Comparisons of the correlation coefficients (Table 83) with the critical value for significance reveal that:
   A. the relationships between concept test scores and the ages of the pupils within a grade are not significant, except for Grade 4 at the application level, where a significant negative relationship exists, and
   B. the relationships between concept test scores and IQ which are significant are those at:
      1. Grades 4 and 5, all levels of understanding, and
      2. Grade 6, at the knowledge and comprehension levels.

Table 78. Concept 7. Application. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	29.550	7.044	2.48
Within	95	4.195		
Total	99			

Table 79. Concept 7. Application. Differences between mean test scores by grade level

Grade		2	3	5	4	6
	Means	7.20	7.40	8.00	8.40	10.25
2	7.20	0	.20	.80	1.20	3.05*
3	7.40		0	.60	1.00	2.85*
5	8.00			0	.40	2.25*
4	8.40				0	1.85*
6	10.25					0

*$p < .05$ (groups listed by rank order)

Table 80. Concept 7. Application. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}(r, 95)$	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	1.287	1.548	1.699	1.804

GPO 807-639-5

Table 81. Concept 7. Comparison of mean test scores by class and level of understanding with critical guessing score

Grade	Levels of Understanding		
	Knowledge	Comprehension	Application
2	8.55*	6.60	7.20*
3	8.70*	7.15*	7.40*
4	9.75*	8.30*	8.40*
5	10.60*	9.30*	8.00*
6	10.95*	11.05*	10.25*

*Mean scores significantly greater than guessing. Critical value = 6.63

Table 82. Concept 7. Number and percent of pupils earning scores equal to or greater than 65% according to grade and level of understanding

Grade	LEVELS OF UNDERSTANDING					
	Knowledge		Comprehension		Application	
	No. of pupils scoring 65% or higher	Percent of class	No. of pupils scoring 65% or higher	Percent of class	No. of pupils scoring 65% or higher	Percent of class
2	14	70	7	35	8	40
3	14	70	9	45	10	50
4	18	90	11	55	15	75
5	18	90	14	70	10	50
6	20	100	20	100	19	95

Number of students per class = 20.

Table 83. Concept 7. Relationship between individual test scores and selected variables according to grade level

Grade	Variable	Knowledge	Comprehension	Application
2	Age	0.104	-0.148	0.075
	IQ	-0.124	0.160	0.223
3	Age	-0.146	-0.011	0.036
	IQ	0.382	-0.254	0.125
4	Age	-0.214	0.150	-0.472*
	IQ	0.493*	0.565*	0.684*
5	Age	-0.124	-0.060	-0.201
	IQ	0.547*	0.606*	0.619*
6	Age	-0.035	-0.047	0.104
	IQ	0.500*	0.462*	0.427

*Correlation coefficients significant at alpha = .05

Concept Eight —Cells come from previously existing cells as a result of the process of division

I. An examination of the mean scores included in Table 84 and Graph VIII reveals that within a grade very little difference exists between the mean scores achieved at the three levels of understanding. Mean scores for the ***knowledge*** and ***application*** subsets showed a progressive increase from grade to grade. For the ***comprehension*** subset two distinct levels of achievement are evident; Grades 2 and 3 low, and Grades 4-6 at a second and higher level.

II. The following results are noted when the three taxonomic levels of understanding are considered separately.

A. Knowledge

1. Significant differences exist among the mean scores earned on the knowledge level questions across grades (Table 85).
2. The mean scores from Grades 4, 5, and 6 are significantly higher than that for Grade 2 (Tables 86 and 87).

B. Comprehension

1. Significant differences exist among the mean scores earned by pupils from different grades (Table 88).
2. The mean scores from Grades 4, 5, and 6 are significantly higher than those for Grades 2 and 3 (Tables 89 and 90).

Table 84. Concept 8. Mean test scores according to grade level and level of understanding

Grade	Levels of Understanding K	C	A
2	6.55	6.65	6.30
3	7.40	6.65	6.75
4	8.05	8.25	7.80
5	8.30	8.30	8.80
6	8.60	8.50	9.20

Possible scores: K—Knowledge, C—Comprehension, and A—Application —12 each.

Table 85. Concept 8. Knowledge. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	13.365	3.398	2.48
Within	95	3.934		
Total	99			

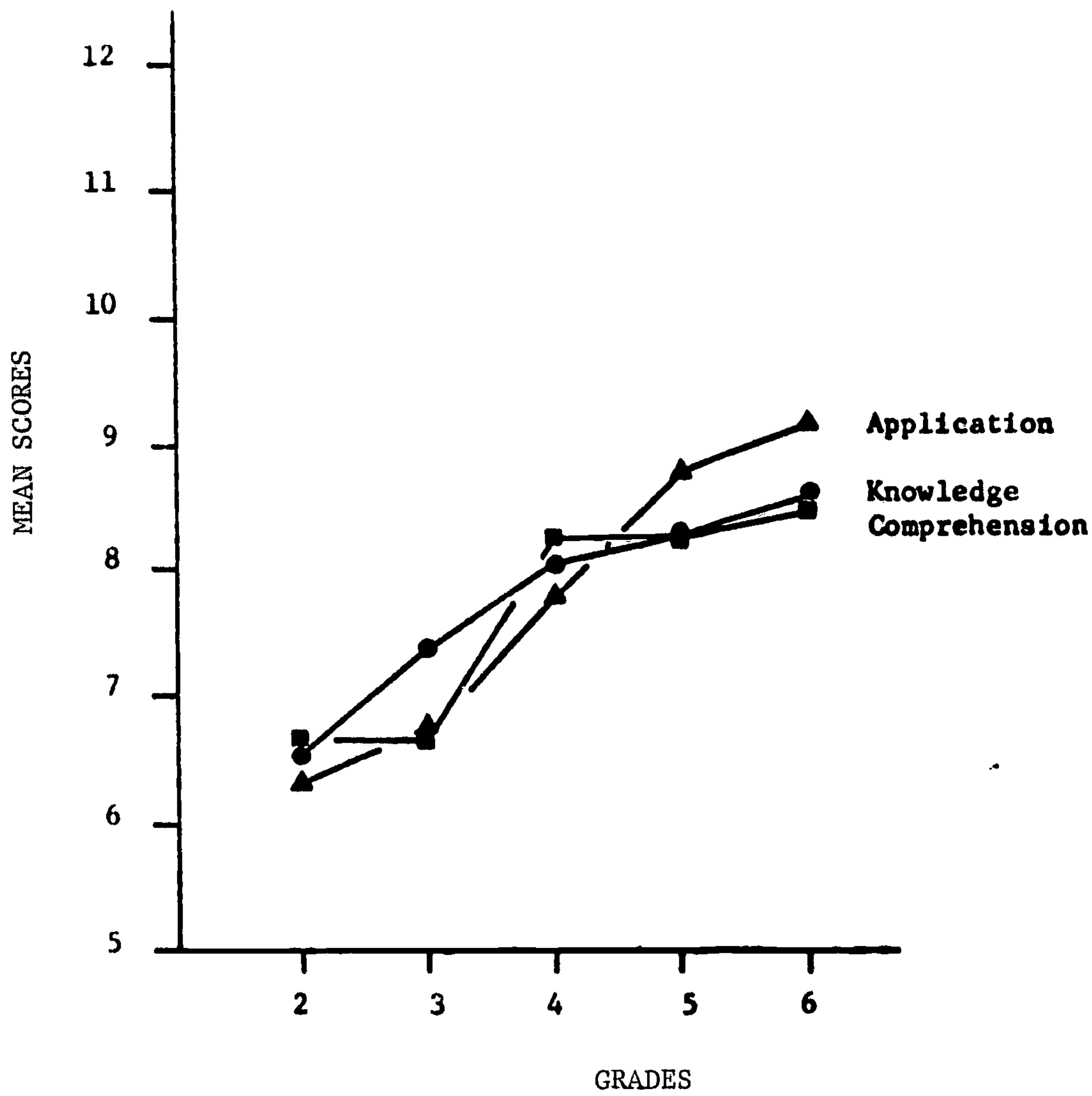
Table 86. Concept 8. Knowledge. Differences between mean test scores by grade level

Grade	Means	2 6.55	3 7.40	4 8.05	5 8.30	6 8.60
2	6.55	0	.85	1.50*	1.75*	2.05*
3	7.40		0	.65	.90	1.20
4	8.05			0	.25	.55
5	8.30				0	.30
6	8.60					0

* $p < .05$ (groups listed by rank order)

Table 87. Concept 8. Knowledge. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}(r, 95)$	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	1.246	1.499	1.645	1.747



Graph VIII. Mean scores vs. grade level, concept 8

Table 88. Concept 8. Comprehension. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	17.515	6.302	2.48
Within	95	2.779		
Total	99			

Table 89. Concept 8. Comprehension. Differences between mean test scores by grade level

Grade	Means	2 6.65	3 6.65	4 8.25	5 8.30	6 8.50
2	6.65	0	0	1.60*	1.65*	1.85*
3	6.65		0	1.60*	1.65*	1.85*
4	8.25			0	.05	.25
5	8.30				0	.20
6	8.50					0

*$p < .05$ (groups listed by rank order)

Table 90. Concept 8. Comprehension. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}$ (r, 95)	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	1.047	1.259	1.382	1.468

C. Application
1. Significant differences exist among the mean scores earned by pupils from the five classes (Table 91).
2. The mean scores for Grades 4, 5, and 6 are significantly higher than that of Grade 2; those of Grades 5 and 6 are significantly higher than the mean score of Grade 3; and, the mean score of Grade 6 is significantly higher than that of Grade 4 (Tables 92 and 93).

III. Comparisons of class mean scores with a critical guessing value (Table 94) reveal that:
A. the mean scores attained by the third through sixth grades at the *knowledge* and *application* levels exceed the guessing value, and
B. the mean scores attained by all grades at the *comprehension* level of understanding exceed the critical guessing value.

IV. The achievement level of 50% of a class scoring 65% or higher (Table 95) is attained or surpassed by:
A. Grades 3-6 at the knowledge level, and
B. Grades 4-6 at the comprehension and application levels of understanding.

V. Comparisons of the correlation coefficients (Table 96) with the critical value for significance reveal that:
A. the relationships between concept test scores and the ages of the pupils within a grade are not significant, and
B. the relationships between concept test scores and IQ which are significant are those at:
1. Grade 4, the knowledge and comprehension levels,
2. Grade 5, the comprehension and application levels of understanding, and
3. Grade 6, the knowledge level.

Table 91. Concept 8. Application. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	31.540	9.680	2.48
Within	95	3.258		
Total	99			

Table 92. Concept 8. Application. Differences between mean test scores by grade level

Grade		2	3	4	5	6
	Means	6.30	6.75	7.80	8.80	9.20
2	6.30	0	.45	1.50*	2.50*	2.90*
3	6.75		0	1.05	2.05*	2.45*
4	7.80			0	1.00	1.40*
5	8.80				0	.40
6	9.20					0

*$p < .05$ (groups listed by rank order)

Table 93. Concept 8. Application. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}(r, 95)$	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	1.134	1.364	1.497	1.590

Table 94. Concept 8. Comparison of mean test scores by class and level of understanding with critical guessing score

Grade	Levels of Understanding		
	Knowledge	Comprehension	Application
2	6.55	6.65*	6.30
3	7.40*	6.65*	6.75*
4	8.05*	8.25*	7.80*
5	8.30*	8.30*	8.80*
6	8.60*	8.50*	9.20*

*Mean scores significantly greater than guessing.
Critical value = 6.63

Table 95. Concept 8. Number and percent of pupils earning scores equal to or greater than 65% according to grade and level of understanding

	LEVELS OF UNDERSTANDING					
	Knowledge		Comprehension		Application	
Grade	No. of pupils scoring 65% or higher	Percent of class	No. of pupils scoring 65% or higher	Percent of class	No. of pupils scoring 65% or higher	Percent of class
2	7	35	8	40	6	30
3	10	50	3	15	7	35
4	14	70	15	75	12	60
5	14	70	14	70	16	80
6	15	75	14	70	17	85

Number of students per class = 20.

Table 96. Concept 8. Relationship between individual test scores and selected variables according to grade level

Grade	Variable	Knowledge	Comprehension	Application
2	Age	-0.157	0.435	-0.017
	IQ	0.303	-0.330	0.108
3	Age	0.077	-0.060	0.114
	IQ	-0.019	0.126	0.087
4	Age	-0.090	-0.272	-0.216
	IQ	0.677*	0.472*	0.418
5	Age	-0.224	-0.288	-0.395
	IQ	0.297	0.462*	0.586*
6	Age	-0.075	-0.335	-0.278
	IQ	0.505*	0.275	0.218

*Correlation coefficients significant at alpha = .05

Concept Nine—DNA is the important molecule concerned with regulation of cell activities

I. Examination of Table 97 and Graph IX reveals an erratic pattern for the mean scores from the *knowledge* subset of questions; Grade 3 is lower than Grade 2 and Grade 5 is lower than Grades 4 and 6. Mean scores for the *comprehension* type questions show a progressive increase from Grade 2 through Grade 5 while mean scores for the *application* type questions increase progressively from Grade 2 through Grade 6 with the exception of a slight decline for Grade 5.

II. The following results are noted when the three taxonomic levels of understanding are considered separately.

A. Knowledge

1. Significant differences exist among the mean scores earned by pupils from different grades (Table 98).
2. The mean scores from Grades 4 and 6 are significantly higher than those from Grades 2 and 3 (Tables 99 and 100).

B. Comprehension

1. Significant differences exist among the mean scores attained by pupils from the five classes (Table 101).
2. The mean scores for the fifth- and sixth-grade classes are significantly higher than the mean score for the second-grade class (Tables 102 and 103).

Table 97. Concept 9. Mean test scores according to grade level and level of understanding

Grade	Levels of Understanding K	C	A
2	7.60	7.40	7.15
3	7.30	7.75	7.55
4	9.20	8.60	8.50
5	8.45	9.25	8.30
6	9.65	9.10	9.25

Possible scores: K–Knowledge, C–Comprehension, and A–Application —12 each.

Table 98. Concept 9. Knowledge. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	20.235	6.372	2.48
Within	95	3.176		
Total	99			

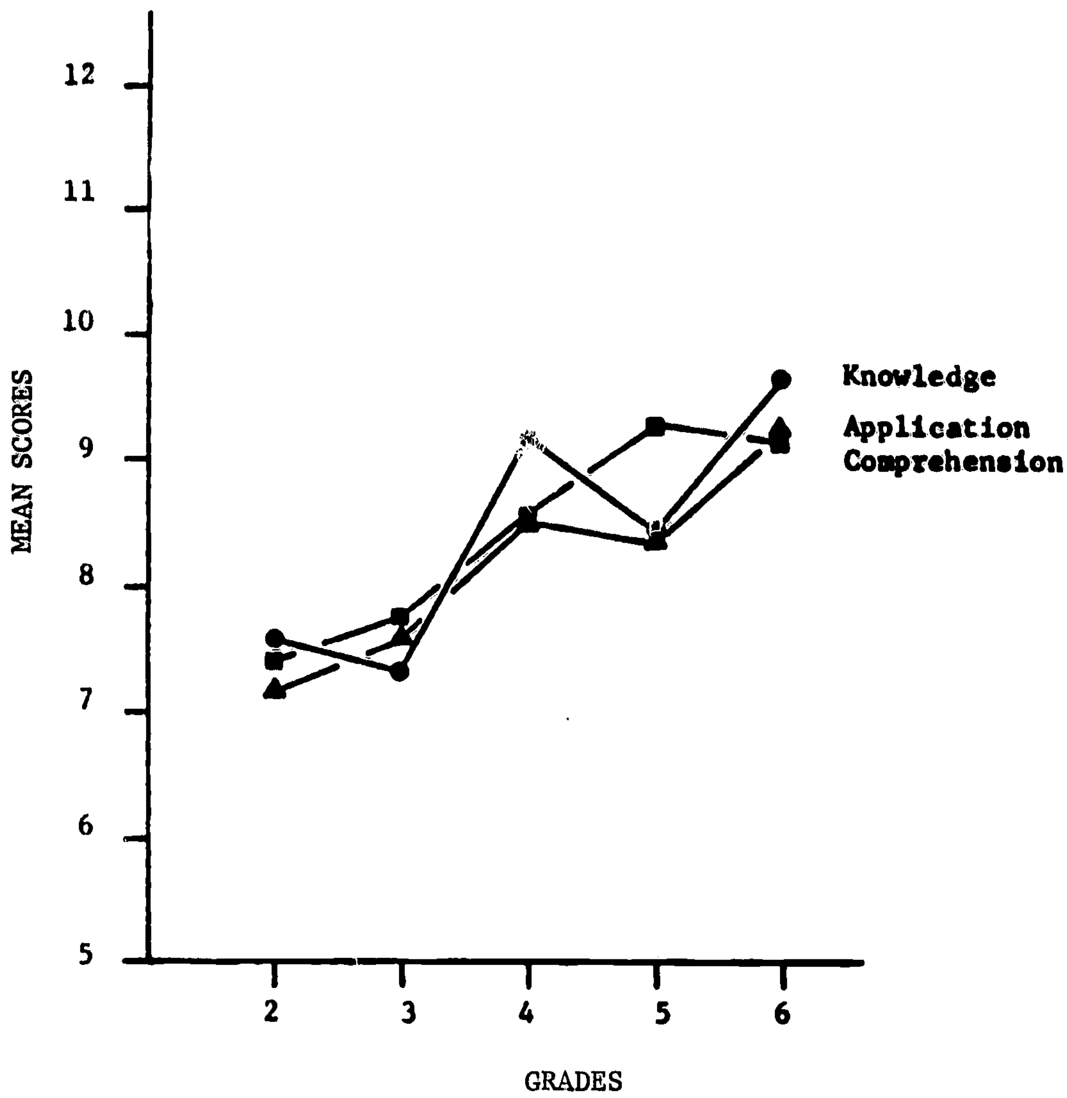
Table 99. Concept 9. Knowledge. Differences between mean test scores by grade level

Grade		3	2	5	4	6
	Means	7.30	7.60	8.45	9.20	9.65
3	7.30	0	.30	1.15	1.90*	2.35*
2	7.60		0	.85	1.60*	2.05*
5	8.45			0	.75	1.20
4	9.20				0	.45
6	9.65					0

*$p < .05$ (groups listed by rank order)

Table 100. Concept 9. Knowledge. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}(r, 95)$	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	1.120	1.347	1.478	1.570



Graph IX. Mean scores vs. grade level, concept 9

Table 101. Concept 9. Comprehension. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	13.365	4.007	2.48
Within	95	3.336		
Total	99			

Table 102. Concept 9. Comprehension. Differences between mean test scores by grade level

Grade		2	3	4	6	5
	Means	7.40	7.75	8.60	9.10	9.25
2	7.40	0	.35	1.20	1.70*	1.85*
3	7.75		0	.85	1.35	1.50
4	8.60			0	.50	.65
6	9.10				0	.15
5	9.25					0

*$p < .05$ (groups listed by rank order)

Table 103. Concept 9. Comprehension. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}(r, 95)$	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	1.148	1.380	1.515	1.609

C. Application
   1. There is a significant difference among the mean scores earned by the classes (Table 104).
   2. The mean score for Grade 6 is significantly higher than that for Grade 2 (Tables 105 and 106).

III. Comparisons of class mean scores with a critical guessing value (Table 107) reveal that all concept test mean scores at all levels of understanding are significantly higher than guessing.

IV. From Table 108 it can be seen that at all levels of understanding at least 50% of each class, with the exception of Grade 3 at the knowledge level and Grade 2 at the application level, achieved or exceeded scores of 65%.

V. Comparisons of the correlation coefficients (Table 109) with the critical value for significance reveal that:
   A. the relationships between concept test scores and the ages of the pupils within a grade are not significant, and
   B. the relationships between concept test scores and IQ which are significant are those at:
      1. Grade 3, the knowledge level,
      2. Grade 4, the application level of understanding, and
      3. Grade 5, the knowledge and comprehension levels.

Table 104. Concept 9. Application. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	13.575	3.220	2.48
Within	95	4.215		
Total	99			

Table 105. Concept 9. Application. Differences between mean test scores by grade level

Grade	Means	2 7.15	3 7.55	5 8.30	4 8.50	6 9.25
2	7.15	0	.40	1.15	1.35	2.10*
3	7.55		0	.75	.95	1.70
5	8.30			0	.20	.95
4	8.50				0	.75
6	9.25					0

*$p < .05$ (groups listed by rank order)

Table 106. Concept 9. Application. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}(r, 95)$	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	1.290	1.551	1.703	1.808

GPO 807-639-4

Table 107. Concept 9. Comparison of mean test scores by class and level of understanding with critical guessing score

Grade	Levels of Understanding		
	Knowledge	Comprehension	Application
2	7.60*	7.40*	7.15*
3	7.30*	7.75*	7.55*
4	9.20*	8.60*	8.50*
5	8.45*	9.25*	8.30*
6	9.65*	9.10*	9.25*

*Mean scores significantly greater than guessing. Critical value = 6.63

Table 108. Concept 9. Number and percent of pupils earning scores equal to or greater than 65% according to grade and level of understanding

	LEVELS OF UNDERSTANDING					
	Knowledge		Comprehension		Application	
Grade	No. of pupils scoring 65% or higher	Percent of class	No. of pupils scoring 65% or higher	Percent of class	No. of pupils scoring 65% or higher	Percent of class
2	10	50	10	50	8	40
3	9	45	11	55	11	55
4	16	80	14	70	13	65
5	14	70	17	85	13	65
6	19	95	18	90	17	85

Number of students per class = 20.

Table 109. Concept 9. Relationship between individual test scores and selected variables according to grade level

Grade	Variable	Knowledge	Comprehension	Application
2	Age	-0.056	0.099	-0.029
	IQ	-0.075	-0.254	0.329
3	Age	-0.129	0.079	0.103
	IQ	0.451*	-0.044	0.347
4	Age	-0.001	-0.225	-0.261
	IQ	0.308	0.140	0.529*
5	Age	-0.343	0.006	0.070
	IQ	0.509*	0.593*	0.339
6	Age	0.292	-0.440	0.004
	IQ	0.340	0.085	0.353

*Correlation coefficients significant at alpha = .05

Concept Ten—DNA replicates itself and also serves as a template for RNA formation involved in regulation of cell activities

I. It is noted from Table 110 that the mean scores at the *knowledge* level, for all classes, exceed those attained at the comprehension and application levels. While the mean scores at the *comprehension* level follow the same general trend from grade to grade as those at the knowledge level, the mean scores for the *application* subset of questions vary little across grades (Graph X).

II. The following results are noted when the three taxonomic levels of understanding are considered separately.

A. Knowledge

1. Significant differences exist among the mean scores earned by pupils from different grades (Table 111).
2. The significant differences are found to exist between the sixth-grade and the second-grade mean scores and between the sixth-grade and the third-grade mean scores (Tables 112 and 113).

B. Comprehension

1. A significant difference exists among the mean scores earned by pupils from different grades (Table 114).

Table 110. Concept 10. Mean test scores according to grade level and level of understanding

Grade	Levels of Understanding K	C	A
2	7.25	6.05	7.05
3	7.25	6.45	7.15
4	8.15	7.75	7.00
5	8.00	7.75	7.30
6	8.75	8.10	7.25

Possible scores: K–Knowledge, C–Comprehension, and A–Application —12 each.

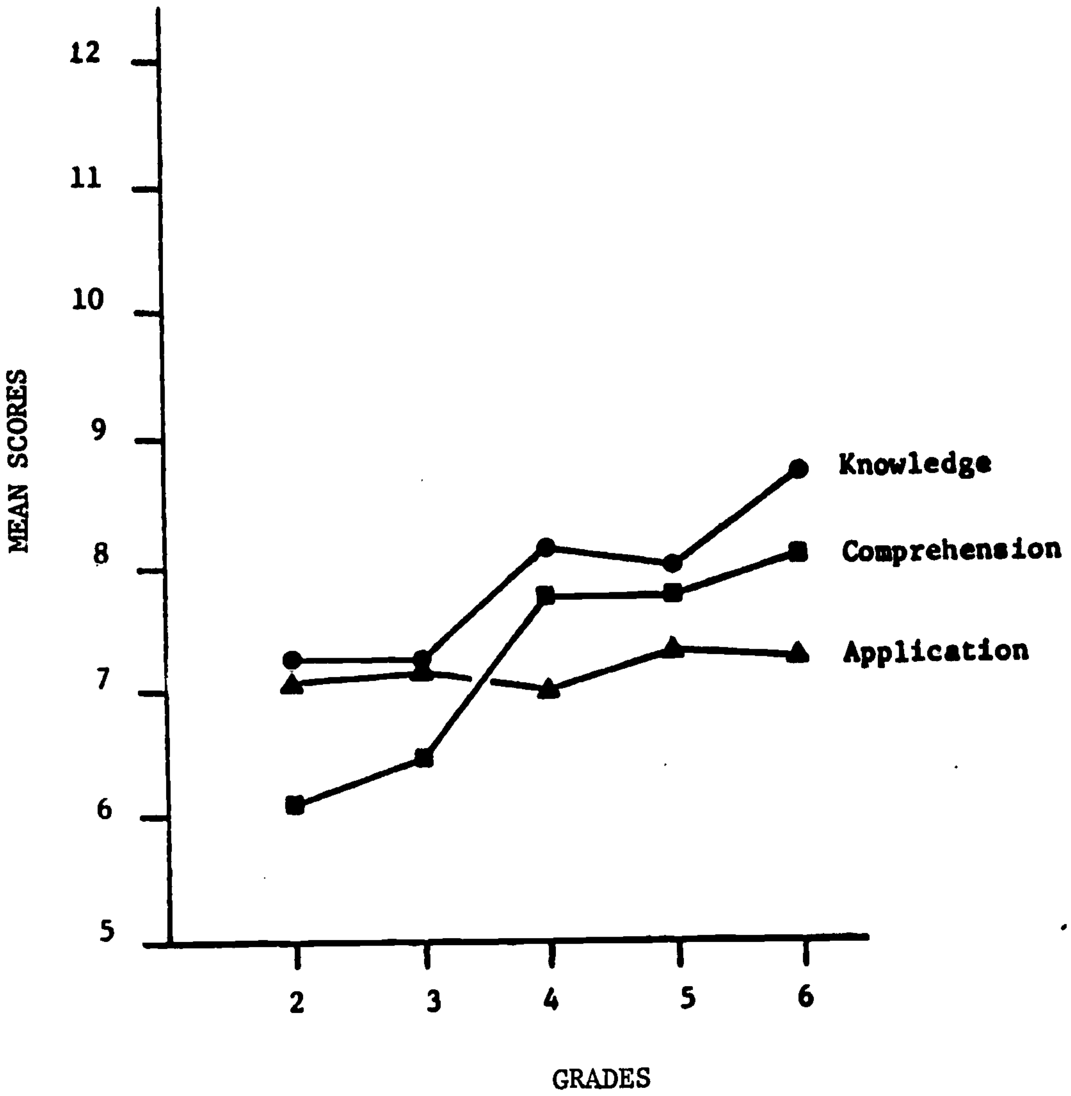
Table 111. Concept 10. Knowledge. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	8.190	3.090	2.48
Within	95	2.651		
Total	99			

Table 112. Concept 10. Knowledge. Differences between mean test scores by grade level

Grade		2	3	5	4	6
	Means	7.25	7.25	8.00	8.15	8.75
2	7.25	0	0	.75	.90	1.50*
3	7.25		0	.75	.90	1.50*
5	8.00			0	.15	.75
4	8.15				0	.60
6	8.75					0

*p < .05 (groups listed by rank order)



Graph X. Mean scores vs. grade level, concept 10

Table 113. Concept 10. Knowledge. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}$ (r, 95)	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	1.023	1.230	1.350	1.434

Table 114. Concept 10. Comprehension. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	16.490	3.866	2.48
Within	95	4.265		
Total	99			

2. The mean score for the sixth grade is found to be significantly different from that earned by the second grade (Tables 115 and 116).

C. Application
No significant differences exist among the classes (Table 117).

III. Comparisons of class mean scores with a critical guessing value (Table 118) reveal that:
A. all concept test mean scores at the knowledge and application levels of understanding exceed the guessing value, and
B. at the comprehension level, the mean scores for Grades 4-6 exceed the guessing value.

IV. The achievement level of 50% of a class scoring 65% or higher (Table 119) is attained or surpassed by:
A. Grades 3-6 at the knowledge level,
B. Grades 4-6 at the comprehension level, and
C. Grades 3 and 6 at the application level.

V. Comparisons of the correlation coefficients (Table 120) with the critical value for significance reveal that:
A. the relationships between concept test scores and the ages of the pupils within a grade which are significant are those at:
1. Grades 2 and 6, the knowledge level (positive), and
2. Grade 3, the knowledge level (negative).
B. the relationships between concept test scores and IQ which are significant are those at:
1. Grade 3, the knowledge level,
2. Grade 4, the comprehension level of understanding, and
3. Grade 6, the comprehension and application levels.

Table 115. Concept 10. Comprehension. Differences between mean test scores by grade level

Grade		2	3	4	5	6
	Means	6.05	6.45	7.75	7.75	8.10
2	6.05	0	.40	1.70	1.70	2.05*
3	6.45		0	1.30	1.30	1.65
4	7.75			0	0	.35
5	7.75				0	.35
6	8.10					0

*$p < .05$ (groups listed by rank order)

Table 116. Concept 10. Comprehension. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}(r, 95)$	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	1.297	1.560	1.713	1.819

Table 117. Concept 10. Application. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	0.325	0.129	2.48
Within	95	2.521		
Total	99			

Table 118. Concept 10. Comparison of mean test scores by class and level of understanding with critical guessing score

Grade	Levels of Understanding		
	Knowledge	Comprehension	Application
2	7.25*	6.05	7.05*
3	7.25*	6.45	7.15*
4	8.15*	7.75*	7.00*
5	8.00*	7.75*	7.30*
6	8.75*	8.10*	7.25*

*Mean scores significantly greater than guessing. Critical value = 6.63

Table 119. Concept 10. Number and percent of pupils earning scores equal to or greater than 65% according to grade and level of understanding

	LEVELS OF UNDERSTANDING					
	Knowledge		Comprehension		Application	
Grade	No. of pupils scoring 65% or higher	Percent of class	No. of pupils scoring 65% or higher	Percent of class	No. of pupils scoring 65% or higher	Percent of class
2	9	45	5	25	9	45
3	11	55	5	25	10	50
4	14	70	10	50	9	45
5	13	65	11	55	9	45
6	17	85	13	65	10	50

Number of students per class = 20.

Table 120. Concept 10. Relationship between individual test scores and selected variables according to grade level

Grade	Variable	Knowledge	Comprehension	Application
2	Age	0.584*	0.152	0.170
	IQ	-0.280	0.310	0.176
3	Age	-0.466*	0.074	0.036
	IQ	0.560*	0.373	0.001
4	Age	0.346	-0.211	0.435
	IQ	0.099	0.577*	-0.043
5	Age	-0.249	0.294	0.102
	IQ	0.314	0.400	0.187
6	Age	0.456*	0.133	-0.154
	IQ	-0.083	0.622*	0.622*

*Correlation coefficients significant at alpha = .05

Concept Eleven—Cells cannot grow to indefinite size

I. Reference to Table 121 and Graph XI reveals that, with the exception of Grade 5, the mean scores of all classes are highest at the *knowledge* level. The mean scores of all classes, with the exception of Grade 3, are lowest at the *application* level of understanding.

II. The following results are noted when the three taxonomic levels of understanding are considered separately.

A. Knowledge

1. The existence of significant differences among the mean scores of the classes is apparent (Table 122).
2. The mean score attained by the sixth-grade class is significantly higher than the mean scores for the classes from Grades 2, 3, 4, and 5 (Tables 123 and 124).

B. Comprehension

1. Significant differences exist among the mean scores attained by the classes (Table 125).

Table 121. Concept 11. Mean test scores according to grade level and level of understanding

Grade	Levels of Understanding		
	K	C	A
2	6.65	6.60	6.45
3	6.75	6.00	6.15
4	8.15	7.30	5.55
5	7.50	8.05	6.90
6	9.40	8.05	6.70

Possible scores: K—Knowledge, C—Comprehension, and A—Application —12 each.

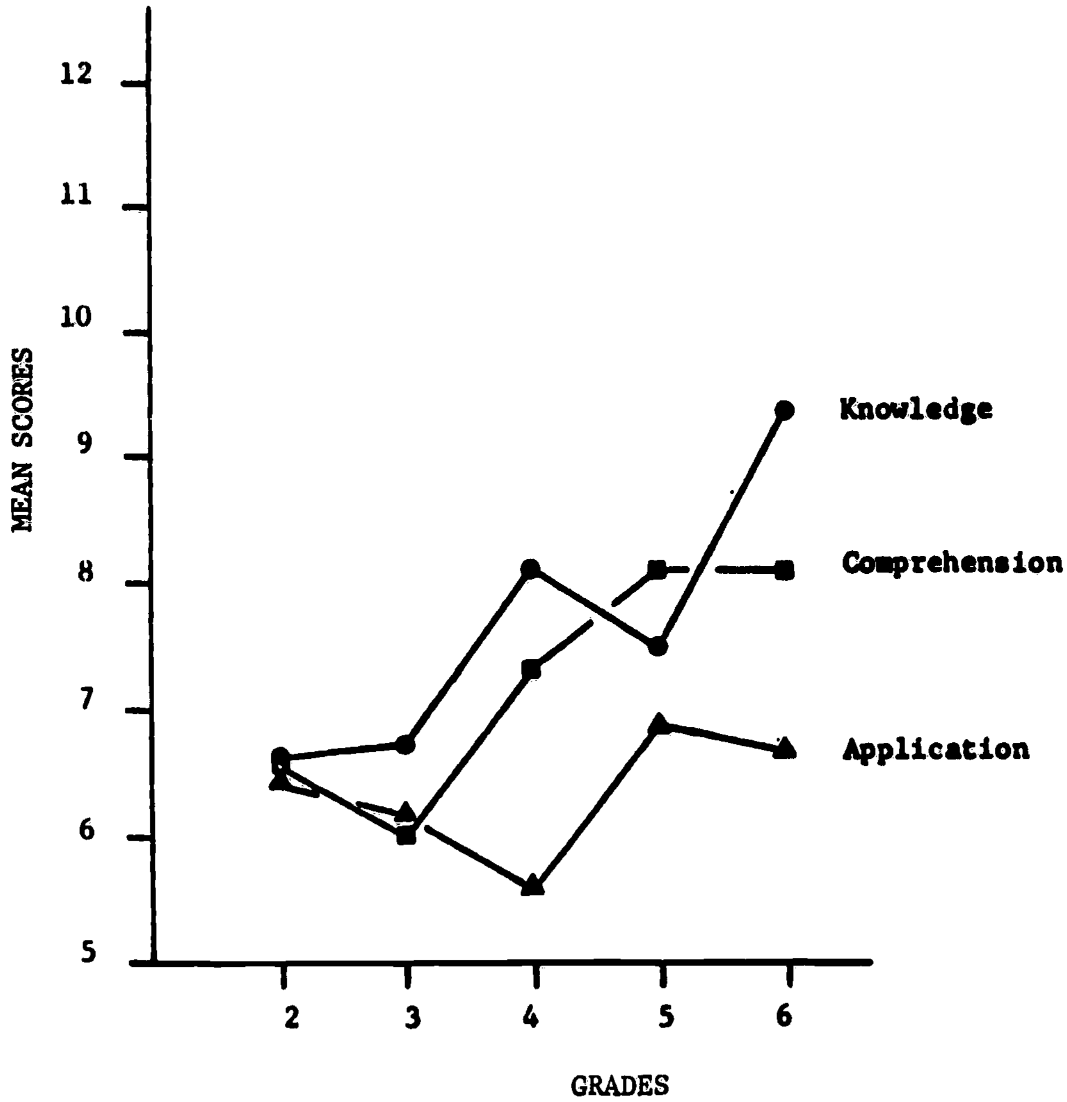
Table 122. Concept 11. Knowledge. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	25.685	6.842	2.48
Within	95	3.754		
Total	99			

Table 123. Concept 11. Knowledge. Differences between mean test scores by grade level

Grade		2	3	5	4	6
	Means	6.65	6.75	7.50	8.15	9.40
2	6.65	0	.10	.85	1.50	2.75*
3	6.75		0	.75	1.40	2.65*
5	7.50			0	.65	1.90*
4	8.15				0	1.25*
6	9.40					0

*$p < .05$ (groups listed by rank order)



Graph XI. Mean scores vs. grade level, concept 11

Table 124. Concept 11. Knowledge. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}(r, 95)$	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	1.217	1.464	1.607	1.707

Table 125. Concept 11. Comprehension. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	16.275	5.243	2.48
Within	95	3.104		
Total	99			

2. The mean scores attained by the classes from Grades 5 and 6 are significantly higher than the mean score of the third-grade class (third grade has the lowest mean score) (Tables 127 and 127).

C. Application
No significant differences exist among the mean scores of the classes (Table 128).

III. Comparisons of the mean scores of all classes at the three levels of understanding with the critical value for random guessing (Table 129) reveal that:
A. at the knowledge level, all mean scores exceed the guessing score,
B. Grades 4-6 exceed the guessing score at the comprehension level, and
C. only Grades 5 and 6 exceed the guessing score at the application level of understanding.

IV. Table 130 shows that the achievement level of 50% of a class scoring 65% or higher is:
A. exceeded only by Grades 4 and 6 at the knowledge level,
B. exceeded by Grades 5 and 6 at the comprehension level, and
C. not attained by any class at the application level of understanding.

V. Comparisons of the correlation coefficients (Table 131) with the critical value for significance reveal that:
A. the relationships between concept test scores and the ages of the pupils within a grade are not significant, and
B. the relationships between concept test scores and IQ which are significant are those at:
1. Grade 2, the knowledge level where a significant negative relationship exists,
2. Grade 4, the application level of understanding, and
3. Grade 5, the knowledge and application levels.

Table 126. Concept 11. Comprehension. Differences between mean test scores by grade level

Grade		3	2	4	5	6
	Means	6.00	6.60	7.30	8.05	8.05
3	6.00	0	.60	1.30	2.05*	2.05*
2	6.60		0	.70	1.45	1.45
4	7.30			0	.75	.75
5	8.05				0	0
6	8.05					0

*$p < .05$ (groups listed by rank order)

Table 127. Concept 11. Comprehension. Critical values for Newman-Keuls test

r	2	3	4	5
$q_{.95}(r, 95)$	2.81	3.38	3.71	3.94
$q_{.95}(r, 95)\sqrt{\frac{MS_{error}}{n}}$	1.107	1.331	1.461	1.552

Table 128. Concept 11. Application. Summary table for the analysis of variance with an alpha of .05

Source	df	MS	F	F (Critical)
Between grades	4	5.575	1.823	2.48
Within	95	3.057		
Total	99			

GPO 807-639-3

Table 129. Concept 11. Comparison of mean test scores by class and level of understanding with critical guessing score

Grade	Levels of Understanding		
	Knowledge	Comprehension	Application
2	6.65*	6.60	6.45
3	6.75*	6.00	6.15
4	8.15*	7.30*	5.55
5	7.50*	8.05*	6.90*
6	9.40*	8.05*	6.70*

*Mean scores significantly greater than guessing. Critical value = 6.63

Table 130. Concept 11. Number and percent of pupils earning scores equal to or greater than 65% according to grade and level of understanding

	LEVELS OF UNDERSTANDING					
	Knowledge		Comprehension		Application	
Grade	No. of pupils scoring 65% or higher	Percent of class	No. of pupils scoring 65% or higher	Percent of class	No. of pupils scoring 65% or higher	Percent of class
2	6	30	4	20	3	15
3	6	30	5	25	3	15
4	12	60	8	40	3	15
5	9	45	13	65	9	45
6	19	95	12	60	8	40

Number of students per class = 20.

Table 131. Concept 11. Relationship between individual test scores and selected variables according to grade level

Grade	Variable	Knowledge	Comprehension	Application
2	Age	0.323	-0.241	-0.022
	IQ	-0.531*	0.007	-0.214
3	Age	-0.036	-0.081	0.145
	IQ	0.154	-0.267	0.172
4	Age	0.119	0.218	0.093
	IQ	0.194	0.161	0.498*
5	Age	-0.361	-0.163	0.036
	IQ	0.654*	0.269	0.535*
6	Age	-0.016	-0.171	0.044
	IQ	0.394	0.184	0.319

*Correlation coefficients significant at alpha = .05

V
CONCLUSIONS AND IMPLICATIONS

CONCLUSIONS CONCERNING CONCEPT GRADE-PLACEMENT (Summarization in Table 132)

A. Concept 1. Cells are parts of living things and living things only.
   1. Concept 1 can be taught to children in Grades 2-6 with equal probability of success if the desired level of mastery is knowledge.
   2. Concept 1 can be taught to children in Grades 2-6 when the desired level of mastery is comprehension or application; however, the probability of success appears greater for children in Grade 4 or above.

B. Concept 2. Cells have a basic structure.
   1. Concept 2 can be taught in Grades 2-6 when the desired level of mastery is knowledge, with the greatest probability of success coming in Grades 4 and above.
   2. Concept 2 cannot be taught at the comprehension level of understanding in Grades 2-6.
   3. Concept 2 can be taught in Grades 4 and 6 at the application level of understanding. Since Grade 4 failed to achieve at the comprehension level, and Grade 5, at both the comprehension and application levels, the greatest probability of success would be in Grade 6 if the desired level of mastery is application.

C. Concept 3. The parts of cells have specific functions.
   1. Concept 3 can be taught in Grades 2-6 with equal success when the desired level of mastery is knowledge.
   2. Concept 3 can be taught at the comprehension level of understanding in Grades 2-6; however, greater probability of success will be in Grades 4-6.
   3. Concept 3 can be taught in Grades 4-6 when the desired level of mastery is application.

D. Concept 4. Plant cells differ in structure depending upon their function.
   1. Concept 4 can be taught in Grades 2-6 when the desired level of mastery is knowledge. Greater probability for success exists for children in Grades 3-6.
   2. Concept 4 can be taught in Grades 3-6 when the desired level of mastery is comprehension or application; however, the probability of success is greater above Grade 3.

E. Concept 5. Animal cells differ in structure depending upon their function.
   1. Concept 5 can be taught in Grades 2-6 when the desired level of mastery is knowledge; however, the probability of success would be greater in Grade 6.
   2. Concept 5 can be taught in Grades 3-6 at the comprehension level of mastery, with a greater probability of success in Grade 6.
   3. Concept 5 may be introduced in Grades 4-6 when the desired level of mastery is application.

F. Concept 6. The activities associated with life are carried on in the cell.
   1. Concept 6 can be taught in Grades 2-6 when the desired level of mastery is knowledge, comprehension, or application. Although at the knowledge level Grade 2 failed to meet one of the criteria of achievement, it warrants inclusion since it did meet the minimal requirements at both the comprehension and application levels.
   2. Since no significant differences in performance exist among the classes, there appears to be little difference in the probability of success in learning the concept at the several grade levels.

G. Concept 7. Organisms differ in size depending upon the number of cells possessed, not the cell size.
1. Concept 7 can be taught in Grades 2-6 when knowledge is the level of mastery desired; however, the greater probability of success is for children in Grades 5 and 6.
2. Concept 7 cannot be introduced below Grade 4 when the comprehension or application levels of mastery are desired since Grade 3 failed to meet all of the criteria for minimal acceptable achievement at the comprehension level. The greater probability of success occurs in Grade 6.

H. Concept 8. Cells come from previously existing cells as a result of the process of division.
1. Concept 8 can be taught in Grades 3-6 when the desired level of mastery is knowledge.
2. Concept 8 can be taught in Grades 4-6, when the desired levels of mastery are comprehension or application. The greater probability of success will be in Grade 6.

I. Concept 9. DNA is the important molecule concerned with regulation of cell activities.
1. Concept 9 can be taught in Grades 2-6 when the desired level of mastery is knowledge or comprehension. Although Grade 3 failed to meet one criterion for acceptable achievement at the knowledge level, it did meet the criteria at both the comprehension and application levels, thus warranting its inclusion here.
2. Concept 9 can be taught in Grades 3-6, when the desired level of mastery is application, with no significant differences in achievement anticipated.

J. Concept 10. DNA replicates itself and also serves as a template for RNA formation involved in regulation of cell activities.
1. Concept 10 can be taught in Grades 3-6 at the knowledge level of understanding; however, the greater probability of success would be in Grade 6.
2. Concept 10 can be introduced in Grades 4-6 with equal probability of success when the desired level of mastery is comprehension.
3. Concept 10 cannot be taught below Grade 6 with any assurance of success when the desired level of mastery is application. Although Grade 3 met the criteria for acceptable achievement, the unsatisfactory achievement of Grades 4 and 5 does not make the introduction of the concept at Grade 3 desirable.

K. Concept 11. Cells cannot grow to indefinite size.
1. Concept 11 can be taught in Grades 4-6 at the knowledge level of mastery. Although Grade 5 failed to meet one of the criteria of achievement at this level, it warrants inclusion since it did meet the minimal requirements at the comprehension level of understanding. The greater probability of success for learning the concept occurs in Grade 6.
2. Concept 11 can be taught in Grades 5 and 6, when the desired level of mastery is comprehension, and no significant difference in achievement is anticipated.
3. Concept 11 cannot be successfully taught in any of the grades when the desired level of mastery is application.

CONCLUSIONS CONCERNING RELATIONSHIPS AMONG THE SELECTED VARIABLES

A. The ability of a pupil, within a given grade, to achieve mastery of a particular concept at any desired level of understanding is not significantly related to his age.

B. The degree of relationship between concept test scores and IQ is greater at the higher grades (Grades 4-6) than at the lower grades (Grades 2 and 3), irrespective of the level of mastery (knowledge, comprehension, or application).

IMPLICATIONS

A. While the classificational concepts are generally assumed to be of the simplest nature and therefore considered the most appropriate type for children in the lower elementary grades, this study produces some evidence that children in the elementary school may encounter difficulties and fail to achieve mastery of such concepts when not given the opportunity to relate the facts included with other meaningful facts, thus, in effect, formulating a correlational concept.

B. Preconceived notions or ideas may be difficult to overcome at the lower grades regardless of counterevidence presented instructionally, when such instruction conflicts with the "logic" of the situation as viewed by the child. An example was the continued belief that large animals, such as elephants, must have larger cells than small animals, such as mice, despite specific instruction that "organisms differ in size depending upon the number of cells possessed, not the cell size."

C. Certain theoretical concepts can be taught successfully, even at the lower elementary level, when they are presented to the children in a concrete manner. That is, utilization of models and diagrammatic representations can aid the child in formulating a concept of abstract ideas.

D. The probability of mastery of certain concepts in science, at a given grade level, may be decreased substantially due to the delayed development of certain mathematical concepts, e.g., area and volume. The lack of mastery of these concepts appears to have contributed substantially to the difficulties encountered by the children with regard to the concept "cells cannot grow to indefinite size," where an understanding of surface area—volume relationships was essential.

E. Certain concepts within the conceptual scheme the biological cell appear to be appropriate for inclusion in the science curriculum of the lower elementary grades.

F. Decisions concerning the inclusion of certain concepts in the science curriculum at specific grade levels are, in part, a function of the level of mastery desired.

G. The level of mastery attained with respect to a concept appears to be, in part, a function of the level of maturity of the children.

Table 132. Summary table showing concepts and relative levels of mastery by grades

Level of Understanding	GRADE LEVEL 2	3	4	5	6	Significant Differences
Concept 1. Cells are parts of living things and living things only (Classificational).						
K	*%	*%	*%	*%	*%	n.s.d.
C	*%	*%	*%	*%	*%	4, 6 > 2; 6 > 3
A	*%	*%	*%	*%	*%	4, 5, 6 > 2, 3
Concept 2. Cells have a basic structure (Classificational).						
K	*%	*%	*%	*%	*%	4, 6 > 2, 3
C			*	*	*	n.s.d.
A			*%	*	*%	6 > 2, 3
Concept 3. The parts of cells have specific functions (Correlational).						
K	*%	*%	*%	*%	*%	n.s.d. (post-hoc)
C	*%	*%	*%	*%	*%	4, 5, 6 > 2; 4, 6 > 3
A	*	*	*%	*%	*%	4, 5, 6 > 2, 3

*—mean score of class significantly greater than guessing
%—class having 50% or more of its members scoring 65% or higher on test
n.s.d.—no significant difference
K–Knowledge, C–Comprehension, A–Application

(continued)

Table 132 (continued)

Level of Understanding	GRADE LEVEL 2	3	4	5	6	Significant Differences
Concept 4. Plant cells differ in structure depending upon their function (Correlational).						
K	*%	*%	*%	*%	*%	3, 4, 5, 6 > 2
C		*%	*%	*%	*%	3, 4, 5, 6 > 2; 6 > 3
A	*	*%	*%	*%	*%	6 > 2
Concept 5. Animal cells differ in structure depending upon their function (Correlational).						
K	*%	*%	*%	*%	*%	6 > 2, 3, 4, 5
C		*%	*%	*%	*%	6 > 2, 3, 4, 5
A		*	*%	*%	*%	4, 5, 6 > 2; 4, 6 > 3
Concept 6. The activities associated with life are carried on in the cell (Correlational).						
K	*	*%	*%	*%	*%	n.s.d.
C	*%	*%	*%	*%	*%	n.s.d.
A	*%	*%	*%	*%	*%	n.s.d. (post-hoc)
Concept 7. Organisms differ in size depending upon the number of cells possessed, not the cell size (Correlational).						
K	*%	*%	*%	*%	*%	5, 6 > 2, 3
C		*	*%	*%	*%	6 > 2, 3, 4, 5; 5 > 2, 3; 4 > 2
A	*	*%	*%	*%	*%	6 > 2, 3, 4, 5
Concept 8. Cells come from previously existing cells as a result of the process of division (Classificational).						
K		*%	*%	*%	*%	4, 5, 6 > 2
C	*	*	*%	*%	*%	4, 5, 6 > 2, 3
A		*	*%	*%	*%	4, 5, 6 > 2; 5, 6 > 3; 6 > 4
Concept 9. DNA is the important molecule concerned with regulation of cell activities (Theoretical).						
K	*%	*	*%	*%	*%	4, 6 > 2, 3
C	*%	*%	*%	*%	*%	5, 6 > 2
A	*	*%	*%	*%	*%	6 > 2
Concept 10. DNA replicates itself and also serves as a template for RNA formation involved in regulation of cell activities (Theoretical).						
K	*	*%	*%	*%	*%	6 > 2, 3
C			*%	*%	*%	6 > 2
A	*	*%	*	*	*%	n.s.d.
Concept 11. Cells cannot grow to indefinite size (Correlational).						
K	*	*	*%	*	*%	6 > 2, 3, 4, 5
C			*	*%	*%	5, 6 > 3
A				*	*	n.s.d.

BIBLIOGRAPHY

Atkin, J. Myron. 1961 (Feb.). Teaching Concepts of Modern Astronomy to Elementary-school Children. *Science Education* 45 (1):54-58.

Ausubel, David P. *The Psychology of Meaningful Verbal Learning.* New York: Grune and Stratton, 1963.

Bailey, Ralph G. 1941 (Feb.). The Difficulty Level of Certain Science Concepts. *Science Education* 25(2):84-89.

Beauchamp, W. L. 1938 (Feb.). Aims in Science Teaching. *The Supervisor's Note Book* 4(5):4. Quoted by Ralph G. Bailey. 1941 (Feb.). The Difficulty Level of Certain Science Concepts. *Science Education* 25 (2):84-89.

Bloom, Benjamin (Ed.). *Taxonomy of Educational Objectives.* New York: David McKay Company, Inc., 1956.

Bronowski, Jacob. *Science and Human Values.* New York: Julian Messner, Inc., 1956.

Butts, David P. 1963. The Degree to Which Children Conceptualize from Science Experience. *Journal of Research in Science Teaching* 1:135-143.

Conant, J. B. *Science and Common Sense.* Oxford: Yale University Press, 1951.

Croxton, W. C. 1936. Pupils' Ability to Generalize. *School Science and Mathematics* 36:627-634.

Deutsche, Jean Marquis. *The Development of Children's Concepts of Causal Relations.* Minneapolis: University of Minnesota Press, 1937.

Einstein, Albert, and Leopold Infeld. *The Evolution of Physics.* New York: Simon and Schuster, 1938.

Gulliksen, Harold. *Theory of Mental Tests.* New York: John Wiley and Sons, Inc., 1950.

Harris, William. 1964. A Technique for Grade Placement in Elementary Science. *Journal of Research in Science Teaching* 2:43-50.

Haupt, George W. *An Experimental Application of a Philosophy of Science Teaching in an Elementary School.* New York: Teachers College, Columbia University, 1935.

Haupt, George W. 1952 (April). Concepts of Magnetism Held by Elementary School Children. *Science Education* 36(3):162-168.

Hedges, William D. *Testing and Evaluation for the Sciences in the Secondary School.* Belmont, Calif.: Wadsworth Publishing Company, Inc., 1966.

Holton, Gerald and Duane H. D. Roller. *Foundations of Modern Physical Science.* Reading, Mass.: Addison-Wesley Publishing Co., Inc., 1958.

Hunt, Earl B. *Concept Learning: An Information Processing Problem.* New York: John Wiley and Sons, 1962.

Inbody, Donald. 1963. Children's Understandings of Natural Phenomena. *Science Education* 47:270-278.

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

Isaacs, Susan. *Intellectual Growth in Young Children.* London: George Routledge and Sons, Ltd., 1930.

King, W. H. The Development of Scientific Concepts in Children. *In* Ira F. Gordon (Ed.), *Human Development (Readings in Research).* Chicago: Scott, Foresman and Co., 1965.

Klausmeier, Herbert J. and William Goodwin. *Learning and Human Abilities.* New York: Harper and Row, 1966.

Kranzer, Herman C. 1963. Children and Their Science Teachers. *Journal of Research in Science Teaching* 1:177-183.

Lachman, Sheldon J. *The Foundations of Science.* New York: Vantage Press, 1960.

Leonelli, Renato. 1955 (Feb.). The Selection and Grade Placement of Physical Science Principles in the Elementary School Curriculum. *Science Education* 39(1):54-56.

Lovell, Kenneth. Concepts in Mathematics. *In* Klausmeier, H. J. and C. W. Harris (Eds.), *Analysis of Concept Learning.* New York: Academic Press, 1966.

McCarthy, Francis. 1952 (Oct.). Age Placement of Selected Science Subject Matter. *Science Education* 36(4):253-254.

McNeil, John D. and Evan R. Keislar. 1962. An Experiment in Validating Objectives for the Curriculum in Elementary School Science. *Science Education* 46:153-157.

Muller, H. J. What Science Is. *In* Levine, G. and Owen Thomas (Eds.), *The Scientist vs. the Humanist*. New York: W. W. Norton and Company, 1963.

Nash, Leonard K. *The Nature of the Natural Sciences*. Boston: Little, Brown and Company, 1963.

National Educational Association. *Commission on the Reorganization of Secondary Education*: Cardinal Principles of Secondary Education. Washington: Government Printing Office, 1918.

National Educational Association. *Report of the Committee on Secondary School Studies.* Washington: Government Printing Office, 1893.

National Science Teachers Association. *Theory Into Action*. Washington: National Science Teachers Association, 1964.

National Society for the Study of Education. *A Program for Teaching Science; Thirty-first Yearbook of the National Society for the Study of Education.* Chicago: The National Society for the Study of Education, 1932.

National Society for the Study of Education. *Science Education in American Schools; Forty-sixth Yearbook of the National Society for the Study of Education.* Chicago: The National Society for the Study of Education, 1947.

Nelson, Pearl Astrid. 1960. Concepts of Light and Sound in the Intermediate Grades. *Science Education* 44(2):142-146.

Oakes, Mervin E. *Children's Explanations of Natural Phenomena.* New York: Teachers College, Columbia University, 1947.

Oxendine, Herbert G. 1958 (Oct.). The Grade Placement of the Physical Science Principle "Sound is Produced by Vibrating Materials" In Relation to Mental Ages. *Science Education* 42(4):354-357.

Peel, E. A. 1964. Learning and Thinking in the School Situation. *Journal of Research in Science Education* 2:227-229.

Pella, M. O. 1966 (Dec.). Concept Learning in Science. *The Science Teacher* 33(9): 31-34.

Piaget, Jean. 1964. Development and Learning. *Journal of Research in Science Teaching* 2(3):176-186.

Popper, Karl R. *The Logic of Scientific Discovery.* New York: Basic Books, 1959.

Read, John. 1958 (Oct.). Present Status and Problems of One Type of Grade-Placement Research. *Science Education* 42(4):349-353.

Reid, Robert W. 1954. An Analysis of the Understanding of Certain Atomic Energy Concepts by Fourth, Fifth, and Sixth Grade Students. *Science Education* 38(1):29.

Shamos, Morris. Science and the Humanities. *In Rethinking Science Education; Fifty-ninth Yearbook of the National Society for the Study of Education.* Chicago: Univ. of Chicago Press, 1960.

Stauss, Nyles G. Materials Used in Teaching and Evaluating the Concepts Related to the Biological Cell in Grades 2-6. *Practical Paper No. 2.* Madison, Wis.: Wisconsin R & D Center for Cognitive Learning, University of Wisconsin, 1968.

Stendler, Celia B. 1962 (Sept.). Elementary Teaching and the Piagetian Theory. *The Science Teacher* 29(5):34-39.

Swanson, Carl P. *The Cell*. Englewood Cliffs: Prentice-Hall, Inc., 1964.

Underhill, Orra. *The Origins and Development of Elementary School Science.* Chicago: Scott, Foresman and Co., 1941.

Walker, Helen M. and Joseph Lev. *Elementary Statistical Methods*. New York: Holt, Rinehart and Winston, Inc., 1958.

Woodruff, A. D. *The Psychology of Teaching*. New York: Longmans, Green & Co., 1951.

GPO 807-638-2.

FROM:

ERI [redacted]

SUIT [redacted]

1735 [redacted]

WAS [redacted]