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

ED 020 910 SE 004 908

THE RELATIONSHIPS BETWEEN CONCEPTS OF FORCE ATTAINED AND MATURITY AS INDICATED BY GRADE LEVELS.

BY- HELGESON, STANLEY L.
WISCONSIN UNIV., MADISON

REPORT NUMBER BR-5-0216 PUB DATE MAR 68
CONTRACT OEC 5-10-154
EDRS PRICE MF-$0.25 HC-$2.28 55P.

DESCRIPTORS- COGNITIVE PROCESSES, *CONCEPT FORMATION, *ELEMENTARY SCHOOL SCIENCE, FORCE, *INSTRUCTION, *LEARNING, *PHYSICAL SCIENCES, SCIENTIFIC CONCEPTS, ACADEMIC ACHIEVEMENT, PHYSICS, SCIENCE CONCEPT LEARNING PROJECT,

REPORTED IS A STUDY CONDUCTED TO DETERMINE THE RELATIVE LEVELS OF UNDERSTANDING OF CERTAIN FORCE CONCEPTS ACHIEVED BY PUPILS IN GRADES 2-6. EVALUATIONS WERE MADE BY MEANS OF PENCIL-AND-PAPER MULTIPLE-CHOICE TYPE TESTS, ONE FOR EACH LEVEL OF UNDERSTANDING--(1) KNOWLEDGE, (2) COMPREHENSION, AND (3) APPLICATION. SUB-PROBLEMS OF THE STUDY WERE (1) TO DETERMINE IF THERE WERE SIGNIFICANT DIFFERENCES IN LEVELS OF ACHIEVEMENT OF PUPILS IN GRADES 2-6, AND (2) TO DETERMINE IF THERE WERE SIGNIFICANT CORRELATIONS BETWEEN I.Q. AND TEST SCORES. UNIFORM INSTRUCTION WAS ACHIEVED AMONG CLASSES BY UTILIZATION OF INSTRUCTIONAL UNITS WHICH WERE DESIGNED FOR THE STUDY. THE REPORT IS DIVIDED INTO FIVE PARTS--(1) THE PROBLEM, (2) REVIEW OF RELATED LITERATURE, (3) PROCEDURE, (4) RESULTS, AND (5) CONCLUSIONS AND IMPLICATIONS. THE CONCLUSION SECTION TABULATES AT WHICH LEVEL OF UNDERSTANDING AND AT WHICH GRADE LEVEL EACH CONCEPT WAS UNDERSTOOD. A BIBLIOGRAPHY IS INCLUDED. LESSON PLANS AND TESTS UTILIZED IN THE PROJECT ARE IN PRACTICAL PAPER NO. 4 OF THE CENTER FOR COGNITIVE LEARNING, "LESSON PLANS AND TESTS OF KNOWLEDGE, COMPREHENSION, AND APPLICATION FOR INSTRUCTION." (DH)

THE RELATIONSHIPS BETWEEN CONCEPTS OF FORCE ATTAINED AND MATURITY AS INDICATED BY GRADE LEVELS

WISCONSIN RESEARCH AND DEVELOPMENT
CENTER FOR
COGNITIVE LEARNING

Technical Report No. 43

THE RELATIONSHIPS BETWEEN CONCEPTS OF FORCE ATTAINED AND MATURITY AS INDICATED BY GRADE LEVELS

Stanley L. Helgeson

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

March 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.

Demonstration-discussion techniques were utilized to instruct pupils in Grades 2-6 in concepts related to the conceptual scheme of force. Data from a posttest designed for measuring three levels of understanding of the concepts --knowledge, comprehension, and application--indicated that most of the concepts can be taught successfully in the elementary grades at the knowledge and comprehension levels; at the application level the concepts can be successfully taught to pupils in the upper elementary grades. Lesson plans and tests utilized in this study are available in Practical Paper No. 4 of the Center.

Herbert J. Klausmeier
Director

CONTENTS

LIST OF TABLES

ABSTRACT

This study was designed to determine the relative levels of understanding of selected concepts from within the conceptual scheme--force--achieved by pupils in Grades 2 through 6 as indicated by scores on knowledge, comprehension and application type tests when all subjects receive comparable instruction.

Subproblems were: a) to determine whether significant differences developed in levels of achievement attained by pupils in Grades 2 through 6, b) to determine whether there were significant correlations between pupil IQ and test scores, and, c) to compare class mean and critical chance scores to determine the percent of each class scoring at least 15 percent above chance.

The selected concepts, in the order of presentation are:

1. Forces are interactions between material bodies, acting as pushes and pulls, that cause changes in motion.
2. A force acting on a body may cause it to accelerate.
3. Forces have magnitude and direction.
4. The acceleration, or change of motion, of a body is proportional to the magnitude of the force acting upon it.
5. Interactions, or forces, between bodies involve actions and reactions.
6. When all the forces acting on a body are in balance, there is no change in its motion.
7. There are different kinds of forces with different origins, but all originate in matter and act upon matter.
8. Forces can be represented by vectors which can be added, subtracted, or resolved into components.

An instructional unit with a fixed order of events utilizing demonstration-discussion techniques was developed to ensure that all pupils received comparable instruction on each concept. Evaluation was based upon paper and pencil multiple-response instruments designed to measure learner achievement at the knowledge, comprehension and application levels. The final sample included 12 pupils per grade.

The achievement criteria were met for the three levels of understanding with specific concepts at the following grade levels:

A. Knowledge
Grade 2: Concepts 1, 2, 3 and 6. Grade 3: Concepts 1, 2, 3, 6 and 7. Grade 4: Concepts 1, 2, 3, 5, 6, 7 and 8. Grade 5: All eight concepts. Grade 6: All eight concepts.

B. Comprehension
Grade 2: Concepts 1, 2, 3, 4, 5, 7 and 8. Grade 3: Concepts 1, 2, 3, 4, 5, 7 and 8. Grade 4: Concepts 1, 2, 3, 4, 5, 7 and 8. Grade 5: All eight concepts. Grade 6: All eight concepts.

C. Application

Grade 2: None of the concepts. Grade 3: Concepts 1, 2 and 8. Grade 4: Concepts 1, 2, 4, 6, 7 and 8. Grade 5: Concepts 1, 2, 4, 6, 7 and 8. Grade 6: All eight concepts.

While scattered instances of statistically significant correlations exist between pupil test scores and IQ within grades, there seems to be no definitive correlation between test scores and IQ within any grade level when considering all three levels of understanding.

Maturity, as indicated by grade level, appears to be a factor in determining success for these eight concepts, particularly at the higher levels of understanding.

I
PROBLEM

INTRODUCTION

The place of concepts in science has been well established by scientists in their attempts to unify their observations and descriptions of nature. The importance of concepts does not end there, however, as is noted by Pella (1966, p. 31):

> Concepts have been cited as the products of scientific processes, as the basis for further scientific studies, 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 to provide for maximum coverage of old and new knowledge is through the development of a classificational system. The formation of concepts or conceptual schemes is one method of classification which results in such economical use of human intelligence.

The theme of parsimony and structural economy that pervades science thus has similar value in science education. Limited by time, the educator faces great and growing quantities of information in every field such that Hurd (1965, p. 7) says, "It is little wonder that we have a crisis in education." The solution to this problem, according to Phenix (1956, p. 140), lies in the use of concepts in defining fields of knowledge.

> . . . the only satisfactory answer to the crisis in learning lies in the formulation and persistent use of key concepts.
>
> . . . concepts of high generality can be found which will provide truer insight into a field than could be gained by mere heaping up of isolated scraps of information . . . .
>
> As knowledge develops, better organizing principles appear from time to time, old disciplines decline and new fields are opened up. Actually, discovery of powerful key concepts is the best way of defining a field of knowledge.

While there is widespread agreement concerning the existence and usefulness of concepts, there is considerable variability in the definitions of concepts as cited by such authors as Kranzer (1963), Russell (1956), Conant (1951), and Einstein and Infeld (1938). For the purposes of this investigation a concept shall be considered 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, p. 32]."

That conceptual content can be handled in the elementary grades when it is consistent with the capacity and readiness of the pupils is indicated by Bailey (1939), McCarthy (1952), and Burlingame (1963), among others. However, the need still exists to determine the capabilities of children in many science disciplines and the difficulty of science concepts at various levels of child development and experiencing (Atkin, 1961; Croxton, 1955).

THE PROBLEM

To determine the relative levels of understanding of selected concepts from within the conceptual scheme force achieved by pupils in Grades 2-6 as indicated by scores on knowledge, comprehension, and application type pencil and paper tests when all subjects receive comparable instruction.

SUBPROBLEMS

1. Are there significant differences in the levels of achievement as indicated by scores on tests designed to measure knowledge, comprehension, and application of selected concepts making up the conceptual scheme force attained by pupils in Grades 2-6?

2. Are there significant correlations between pupil IQ scores and the scores achieved on the knowledge, comprehension, and application tests?

3. In which grades and at what levels of understanding are the following criteria met for each concept?

   a. The mean score earned by the pupils is significantly better than chance.

   b. At least 50% of the pupils earn scores that are at least 15% above chance.

HISTORICAL BACKGROUND

Although the use of concepts in the teaching of science is a relatively recent development in science education, forerunners of this approach may be traced back to the late 1800's. According to Underhill (1941), the first detailed elementary science program of significance was formulated by William T. Harris in 1871. While the use of science concepts as such was not indicated, this curriculum was organized within the specialized sciences and emphasized ideas and their relationships in making learning meaningful. Thus, the work of Harris might be considered as a starting point of the trend toward a concept-oriented curriculum based upon the structure of knowledge.

During this same period of time, G. Stanley Hall and Colonel Francis Parker set forth general philosophies of education supporting nature study. Much of the developmental work was done by Wilbur S. Jackman and Henry H. Straight in the attempt to devise an elementary school program with science as the core (Smith, 1963). Jackman stressed the understanding of significant ideas and emphasized the part played by the generalizations of science as guides to organization. The need for first-hand experience was viewed as a basis from which to draw the generalizations of science in Jackman's outline for nature study (Underhill, 1941).

Three leaders of the nature study movement, all at Cornell University, were Liberty Hyde Bailey, Anna Botsford Comstock, and John L. Spencer. As a result of the work of these people, Comstock's Handbook of Nature Study and the Cornell nature-study leaflets had a widespread impact upon elementary schools. Nature study, like object teaching before it, was largely based on the principles of faculty psychology and on serial development of abilities (Smith, 1963). Educational theory was changing, however, toward a more generalized idea of mental discipline which tended to oppose the limitation of the study of nature to observation only and began to emphasize the significance of insight and understanding (Underhill, 1941).

The development of two schools of thought within the nature-study movement is noted by Weller and Caldwell (1933); the one tending toward sentimentalism and dying out, the other surviving as the foundation of current elementary school science. The first view considered the emotions and feelings while the second regarded the intellect and the necessity of training for accurate observation and clear thinking. As one of the group viewing nature-study as training for the intellect, Downing (1907, p. 194) says:

> Some unifying concept must be introduced or the course of study becomes fragmented, resulting in a series of uncoordinated efforts that lose their cumulative effect. In a course aiming to develop thought power this unifying factor would best be a series of logically related ideas or a dominant concept.... We must seek then some unifying idea in nature-study sufficiently complex to insure an increasing difficulty commensurate with the increasing power of the pupils.

In what seems to be a development of Jackman's idea concerning generalizations of science, Downing suggested evolution as a unifying idea in the teaching of nature-study.

By the 1920's with the conflicting points of view, and with much of nature-study characterized by anthropomorphism, the resulting confusion yielded much study about science with an emphasis on isolated facts rather than on generalizations; as a result interest in nature-study began to fade. The educational climate was changing in response to the pragmatic influence of such men as Charles Pierce, William James, and John Dewey. Within the framework of pragmatic theory, learning was held to be largely dependent upon experience. Thus while Dewey

(1916) was concerned with generalizations and ideas of science, he held the methodology of science in higher regard as a means of teaching science.

Probably one of the greatest influences on elementary school science and on the conceptual approach to science teaching was the work of Gerald S. Craig. Craig (1927) viewed science in the elementary school as a part of general education and saw the concepts of science as having effects not limited to the fields of science. In the Thirty-first Yearbook of the National Society for the Study of Education, which was devoted to the teaching of science, Craig stresses the importance of the concepts of science (p. 134).

> These concepts are of fundamental importance to laymen as well as to scientists....They are a part of the priceless heritage that must be passed on to future generations, and they are fundamental to intelligent living. They should not be treasured away in libraries, known only to a few specialists, but rather should be understood by the masses.

Widespread adoption of Craig's views did not occur rapidly in practice, however. Educational theory of the time, reflecting the influences of stimulus-response psychology, adhered to the belief that children were limited in their ability to handle generalizations. With the growth of the life adjustment movement in the 1940's, increased emphasis was placed upon satisfying the daily needs of the child in his relationship with his immediate environment. As a result, the application of science concepts to specific problems was considered more important than the use of the structure of the discipline in the teaching of science.

Concern for life adjustment is expressed in the Forty-sixth Yearbook of the National Society for the Study of Education (1947, pp. 26-27), wherein emphasis is placed upon the teaching of science concepts for understanding and functional use.

> To recognize information as an objective of science instruction, as is done here, is not to indorse the acquisition of a body of isolated facts whose usefulness is limited to the particular science period in which they are learned or recited....
>
> Science concepts must also be taught so that they will be <u>functional</u>. It is one thing to be able to repeat Boyle's law of gases. It may be quite another thing to be able to identify the operation of the law under new conditions or to be able to control phenomena through the use of the law....
>
> The critical element in functional concepts and principles, as in functional information, is understanding.

The tenor of the times is reflected in the foregoing viewpoint; the value of conceptual knowledge was largely in its applicability, but there was increasing importance attached to understanding.

The two decade period from 1945 to 1965 has been marked by sweeping changes in science, closely paralleled by changes in science teaching. The space activities stimulated great interest in science education and precipitated a widespread evaluation of science content and instructional techniques. It is perhaps indicative that the Fifty-ninth Yearbook of the National Society for the Study of Education is entitled <u>Rethinking Science Education</u>. In this Yearbook, considerable importance is assigned to the use of concepts in the teaching of science. Similar trends are apparent in most of the new curricula developed for the secondary level in biology, chemistry and physics as well as in science texts designed for pupils in the elementary schools. The National Science Teachers Association publication, <u>Theory Into Action</u> (1964, p. 9), perhaps establishes the tone for much of the current practices by setting forth a series of basic conceptual schemes designed to serve as unifying structures for science instruction in Grades 1-12. The emphasis upon science itself in the teaching of science is seen in the statement, "The strategies of learning must be related to the conditions that will lead to an understanding of the conceptual structures of science and of the modes of scientific inquiry."

NATURE OF SCIENCE

The natural world is characterized by an abundance of widely varying phenomena. In order to be able to grasp some of the meaning of his environment, man must adopt some point of view, some frame of reference, for observing the world. One method of approaching this vast array in an efficient and useful manner is through science. As Nash (1963, p. 3) says, "Science is a way of looking at the world." By means of this frame of reference, man is able to impose some order upon his environment in his attempts to understand nature.

This understanding is a product of science and is expressed in the form of concepts that explain the facts of the universe. Such a product is not a finite, static body of knowledge, although science does deal with facts which might be considered finite, but is rather a dynamic series of approximations of the truth. The concepts that serve to explain nature, then, are to be considered as tentative and useful in the degree to which they are able to predict future phenomena. As Pella (1966) notes, concepts as such should not be considered as either true or false, but rather as adequate or inadequate.

If science is to be a really useful frame of reference for viewing the world, it cannot be satisfied with the production of concepts which explain only isolated phenomena. It must instead, in the words of Bronowski (1965, p. 16), "search to discover unity in the wild variety of nature." Such unity comes about by determining the interrelatedness of observed phenomena and events. This interrelationship brings to science a unifying structure composed of conceptual schemes which are statements of patterns of relationships among observed phenomena. Conant (1951, p. 25) says of science:

> Science is an interconnected series of concepts and conceptual schemes that have developed as a result of experimentation and observation and are fruitful of further experimentation and observation.

Again, it should be noted that these statements are not static proclamations without flexibility, but are, in the view of Patton (1962) statements of probability concerning nature which must be interpreted in light of present knowledge.

Subsequent investigations contribute more information which in turn is used to modify existing statements and to suggest areas of further study. Science, then, is not simply a product but is also a process of acquiring understanding. In the words of Lachman (1960, p. 13), "Science is a knowledge-generating activity." As such it is continuous and cummulative, serving to correct itself as it proceeds. This procedure often involves, to one degree or another, observation, measurement, interpretation of data, hypothesis forming and testing, and experimental procedures. However, as Muller (1963, p. 13) notes, "Ultimately the unity of science lies in the logic not the materials or the specific techniques of its inquiry." Thus it is that Roller (1960, p. 16) says,

> Science is concerned with finding out how the world ticks through the interactions of observations, ideas and controlled experiments unified by concepts or conceptual schemes. Science is concerned with ideas not things, although the ideas often are ideas about things. The ideas are created in men's minds.

PSYCHOLOGICAL CONSIDERATIONS

Both Piaget and Bruner have suggested that psychology has two bases of application with respect to education, namely, the development of the child and the evolution of a learning theory.

From a consideration of the present understanding of human learning it appears, according to Bruner (1966), that the accretion of knowledge is not a continuous growth but is more like a staircase with a series of spurts and rests or stages. These stages are considered by Bruner, Piaget, Lovell and others, to have certain characteristics. The first stages are highly manipulative, characterized by unstable and single track attention in which knowing is essentially, as Bruner (p. 27) puts it, "knowing how to do." There follows a period in which the child is able to represent greater pieces of his environment by imagery and which reaches a peak at about the ages of five to seven. Finally, around adolescence, language becomes important as a medium of thought and the child is able to deal with his environment by means of symbols and abstractions.

To be successful, then, a learning theory must take cognizance of the development of the pupil. As Stendler (1962, p. 37) notes, the limits are established by maturation such that, "sixteen-year-old thinkers can never be made of six-year-olds." From the work of Inhelder and Piaget (1958), Lovell (1966), and Elkind (1961), it appears that there is a lower limit beyond which the child is unable to grasp certain ideas or concepts, such as those related to conservation. This factor, from Bruner's point of view, has roots both in the motivation of the learner and in his past experience.

With respect to the latter, Bruner (1966) suggests that the necessary experience can be provided for the child in such a way as to increase his readiness to deal with a concept or idea. Along a similar line, Waetjen (1965) notes that a child's ability to cope with new material can be effectively increased by first presenting the general concepts under which the child may include new knowledge. The efficiency of handling information through the use of concepts is pointed out by Ivany (1966, p. 37):

> The human organism has a built-in "gating" system that allows it to exist in such a milieu of information by selecting out those pieces of information with which it will cope and gating out much other information that is perhaps relevant but which, in addition to all other information input, would create utter chaos in the human nervous system. Thus, any concept that the scientist forms must of necessity be a concept formulated on the basis of limited and selected information.

The importance of motivation has long been stressed by educational psychologists. In this regard, Keislar (1962) views extrinsic reinforcement as an erroneous technique, suggesting instead that a teaching strategy relying upon intrinsic reinforcement is far more effective. It is just such intrinsic motivation that Bruner (1966, p. 30) sees as arising from the activity of learning:

> ...cognitive or intellectual mastery is rewarding. It is particularly so when the learner recognizes the cumulative power of learning, that learning one thing permits him to go on to something that before was out of reach, and so on toward such perfection as one may reach.

Thus it follows that a learning theory as it pertains to science instruction must ultimately come to grips with the structure of the knowledge itself. The conceptual interrelatedness of science makes it possible in the teaching of science to proceed from relatively concrete aspects of a concept at one age level to more precise and abstract understandings at another age level. The value of such an approach is noted in <u>Theory Into Action</u> (National Science Teachers Association 1964, pp. 9-10):

> The conceptual structure ties past experience to the present and serves as a guide for the comprehension and assimilation of new facts and concepts. It serves as a basis for prediction of what will happen in a new problem or situation....
>
> The ability to form science concepts depends upon the learner's own background and the conditions under which he is taught. To insure in some measure the likelihood that a concept will be acquired, it must be presented and used in different contexts. In a well-organized course of study, concepts formed early in the year are used to develop new concepts that occur later. Concepts are most easily acquired when familiar and concrete perceptual materials are used. To enlarge the understanding of a concept requires that it be taught many times at different levels of abstraction.

II
REVIEW OF RELATED LITERATURE

The importance of concepts in education has long been noted and discussed. However, the relationships among concepts and educational processes have not been clearly delineated. In this respect Woodruff (1964, p. 81) notes:

> There has been a constant inference that concepts have a significant place in man's thinking process, but not until recently has anyone drawn a clear picture of the nature of a concept or of its actual relationship to behavior. The relationship of concepts to subject matter has been equally vague but has been consistently inferred. Concepts are closely identified with knowledge. . . .
>
> Thus knowledge is again receiving major attention but of a different kind. Nevertheless, there are still few, if any, hints in the literature that there may be a difference between verbal knowledge and conceptual knowledge, and this is turning out to be a problem of major proportions to education.

Investigations concerned with concepts have varied over a broad range of directions and aspects but have persisted since the early part of the century. Selected studies from this range concerning science concepts in the elementary school will be considered under the following three general categories:

1) Studies dealing with the determination of what science concepts are held by children prior to formal instruction; these have often been primarily psychologically oriented.
2. Investigations concerned with the appropriateness of certain science concepts for instruction of children of specific ages, grade levels, mental abilities or maturational stages.
3) Attempts to evaluate the kinds or levels of understandings of science concepts achieved by elementary school children as a result of certain instructional procedures.

DETERMINATION OF CONCEPTS HELD BY CHILDREN PRIOR TO INSTRUCTION

With his investigation of the development of children's concepts of causality, Piaget (1930) established a point of departure for many studies of the growth of scientific concepts. In his clinical interview technique, Piaget utilized three methods of eliciting explanations from children. The first method involved strictly verbal questions; the second consisted of half verbal and half practical questions wherein the movement of clouds, rivers or parts of machines were mentioned to the child who was then asked to explain this phenomenon; the third method involved simple experiments carried out before the child who was then asked to explain what he observed. Piaget found a sequence of 17 types of causal explanation, each characteristic of different stages of development. As a result of this and subsequent investigations, Piaget (1964) elaborated a theory of cognitive development in which he identified the four major stages in the development of the child:

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

While Piaget's work provided the impetus for many later concept studies, the findings of such investigations were often in contrast to those of Piaget. One such study is that reported by Deutsche (1937) who investigated the development of children's concepts of causal reasoning with 732 pupils in Grades 3-8. The test she used consisted of two forms: the first form involved demonstrations followed by questions asking for explanations of observed phenomena, the second involved only questions. The pupils' answers were rated as to adequacy by 13 judges and the rating values were then converted to weighted scores.

Deutsche found that there was a much higher percentage of naturalistic answers than Piaget reported and concluded that the development of children's reasoning did not follow the stages suggested by Piaget. However, she found the greatest increase in scores occurred between the ages of 11 and 12, which is in accordance with the age set by Piaget as that at which logical and mechanical thinking appears. Further, she found that there was a very low correlation between intelligence and scores within any single age group but that there was a fairly high relationship between school grade and score, even within a single age group.

Oakes (1947), in a study he considered to be an extension of Piaget's work, analyzed the answers given by children to direct questions regarding various natural phenomena. He also used questions which were entirely verbal and questions which were based upon demonstrations in calling for explanations of natural phenomena. Seventy-seven pupils in kindergarten and 24 pupils in each of Grades 2, 4 and 6 were interviewed and their responses categorized as physical, non-physical, or, failure to explain. He concluded:

1. Each subject, regardless of age, mental ability, or grade level, gave explanations of a wide variety of types. All types of answers were given by all age groups.
2. No evidence was found to corroborate Piaget's interpretation that there is a definite stage in the child's thinking which is characteristic of a given age. The types of answers given by these subjects were influenced more by the nature of the problem, the way the question was worded, the child's background experience, and his vocabulary than by any other so-called mental structure for a given age.
3. Although a few responses were enigmatic, the great majority were matter-of-fact, non-metaphysical; in other words naturalistic.
4. In general, understanding of essential relationships increases with age.

In a similar study, King (1964) investigated the responses of more than 1200 children to a schedule of 70 questions dealing with estimation of length, time, direction; with volume, weight, shadows, night, sky; and with growth of living things, seasons, etc. He found that:

1) Answers to 24 of the questions showed a steady increase with age; the questions could all be answered by experience without formal teaching.
2) Thirteen of the questions showed definite confusion and very little increase of correct response with age; these topics could not be easily understood without a more formal approach to supplement experience.
3) Where children had the opportunity to give free answers to questions on sky and night, the types of responses were spread through all age groups with no one type of answer being typical of any age group.

From this he concludes that the evidence does not support Piaget's contention that there is a definite stage in the child's thinking which is characteristic of a given age; that the type of response is apt to be determined by the question, and that this is as likely to be true for adults as for children. He notes (p.276) with respect to the questions on night and sky, "In both cases, with increase of age, reasoning gradually replaced descriptive words, percepts gave way to concepts."

Inbody (1963) used a demonstration-interview technique in questioning 50 kindergarten pupils to determine the extent of their understanding of selected physical phenomena. The phenomena were selected by an analysis of widely used text series. The procedure followed was one of showing the child certain materials and asking him to predict what would happen under given circumstances, performing the demonstration and having the child state what happened, and then asking for the child's explanation of the phenomena.

Inbody noted (p. 275) that, "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." He concluded that young children are capable of understanding cause and effect relationships, especially in events with which they have direct contact, but that adult logic is often meaningless to children and may lead to overgeneralization and verbalization.

A somewhat different approach was employed by Silano (1952) in his study to determine what information children possessed concerning the concept of magnetic phenomena and what processes were involved in children's thoughts. He presented pupils in first and third grades with magnets and strips of metals and observed the children experimenting with the apparatus. During the period of free discussion which followed, records were made of all pertinent discussion among the children. He found that the children's spontaneous remarks could be classified into four major categories that were very similar for pupils in both grades, but that the younger children were more concerned with what happened while the older pupils were more concerned with why it happened. He concluded that teachers might best learn what and how the child thinks by listening to the child's verbal expression without interrupting, and that science instruction in the early grades should be chiefly in the form of direct experience.

Haupt (1952) attempted to determine age and grade differences in children's experiences with, and explanations of, magnetism and whether children's concepts of magnetism parallel the historical development of man's knowledge of the subject. Pupils in Grades 1-7 were interviewed while being permitted to play with magnets and other materials. Haupt found that with respect to the laws of magnetism, children in the lower grades had attained to concepts that were equivalent in complexity and maturity to those from children in the higher grades. He notes (p. 168) that, "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."

Yuckenberg (1962) investigated the preinstructional knowledge that first grade children had acquired concerning certain concepts of astronomy. Ten questions designed to determine the pupil's knowledge about simple concepts concerning the sun, moon, day, night and gravity were developed in consultation with an expert in the teaching of elementary science. The concepts held by these children seemed to show that their immediate knowledge had been extended to include many of the concepts held by adults. Yuckenberg concluded that it is possible to lay a foundation in the first grade for much of the knowledge essential to astronomical understandings in the later grades, and that, since children showed a great deal of interest in the sun, moon, and earth and had some information about these concepts, it might be wise to begin a study of astronomy at an early age.

In another investigation concerning first grade pupils, Olmsted (1964) inventoried the information such pupils had concerning 11 concepts found to be common to five recently published first grade textbooks. Eighteen questions which included 30 different ideas inherent in the 11 concepts were the basis of individual interviews with 140 randomly selected beginning first grade pupils. He found:

1) The evidence suggested that more difficult science concepts could be introduced in the first grade.
2) It appeared that more physical science concepts could be included in first grade texts than is presently the case.
3) Differences between responses by boys and girls seemed to be of little concern.

APPROPRIATENESS OF CERTAIN SCIENCE CONCEPTS

Studies concerned with determining the appropriateness of specific science concepts for children with certain characteristics are based to a large extent upon the assumption that children are able to generalize. The validity of such an assumption was the basis of an investigation by Croxton (1936). More specifically, he attempted to determine whether pupils in Grades K–8 were able to formulate and apply a principle after exposure to the essential experience basis in the form of demonstrations or directed play. He found that children at all grade levels were able to generalize, that is, to formulate and apply principles, but that children in the higher primary, intermediate and junior high school grades were considerably more successful than those in kindergarten and lower primary grades. The higher scores earned by junior high school pupils, he concluded, were not so much due to superior ability to generalize as to added experience.

A slightly different approach was followed by Bailey (1939) who studied the extent to which pupils at different grade levels and with differing mental abilities were able to secure an understanding of certain science concepts. The concepts involved facts and principles necessary to the comprehension of power and were included in a science unit presented to pupils in Grades 6-9. Treatment of pupil scores was based on the grouping of pupils by sex and mental ability. Bailey found that only the boys of high mental ability were consistently able to do satisfactory work on the unit;

girls of high mental ability exhibited irregular achievement; boys and girls of low and middle ability groups were unable to develop a satisfactory understanding of the unit.

McCarthy (1952) investigated the problem of where certain facts and principles of science could be taught profitably for the first time. Three experiments were selected on the basis of simplicity of concept, ease of demonstration and minimum complex reasoning required. The lever, the pulley and the inclined plane were used. Children in Grades K--4 were tested but most of the testing involved second grade pupils. McCarthy concluded that these three experiments involving concepts concerning work as defined in physics were suitable for the second grade.

Reid (1954) analyzed the understanding of certain atomic energy concepts by pupils in Grades 4, 5, and 6. He found that after instruction, pupils in all grades made significant gains as measured by a multiple choice test and that groups seemed to gain more and show more understanding with added maturity. He concluded that many children in Grades 4, 5, and 6, under certain methods of instruction, could benefit from technical atomic energy instruction.

A different technique of determining the appropriateness of concepts for elementary school pupils was used by Leonelli (1955) who conducted a survey of elementary science specialists and elementary teachers engaged in teaching science. He attempted to determine the physical science principles which should be included in the curriculum for Grades 1-6, the reason for inclusion of the principle and the grade or grades wherein the principle should be introduced.

Eighty-four persons answered the portions of the survey dealing with the inclusion of the principles and reasons for their inclusion, and 80 persons answered that portion dealing with grade placement. Of the 81 principles presented, the majority of the combined respondents considered 72 as being acceptable for inclusion in the curriculum, with a majority of the specialists favoring retention of 48 of the principles and a majority of the teachers favoring retention of 72 of the principles. From the list of aims provided as reasons for inclusion of the principles, the majority of respondents felt that the most important was that the principle contributed to a change in pupil behavior through an interest in and an interpretation of the environment. While there was a lack of agreement on the placement of a given principle in any one grade, areas of two or three grades were often designated as appropriate for the introduction of the principle.

In a study involving 15 elementary schools and 700 pupils in Grades 4 and 6, Oxendine (1958) attempted to determine the appropriate grade placement of the physical science principle that sound is produced by vibrating material. The pupils were pretested, randomly separated into two groups with the experimental group given a lecture-demonstration by the classroom teacher and the control group given science booklets to read, and then posttested. Oxendine concluded that the mental age level of 11-12 was the point where pupils indicated mastery of the text, and that this principle might most profitably be introduced at the sixth grade level.

Read (1958) summarized more than twenty studies all of which attempted to determine whether pupils could learn to apply some basic principles of science in a written test and whether mental age and grade level were factors in such learning. The procedure involved pretesting, a demonstration of a single principle accompanied by an oral exposition, and immediate posttesting. Most of the studies were conducted in five different schools and included two grades with a total number of pupils ranging from 175 to 250. From these studies, Read concluded that both mental age and maturation are factors in learning to apply basic principles of science. He also predicted (p. 352) that "many of these basic science principles will be found capable of being learned by a substantial part of classes at lower grade levels than have traditionally been exposed to either the principles or the method."

The acquisition of concepts of light and sound by 118 pupils in the intermediate grades was investigated by Nelson (1960). Instruction was carried on by teachers who had participated in a workshop in physical science and then followed their own methods in teaching the pupils. Nelson found that:

1) Instruction produced a significant gain in 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) Pupils from the relatively high social status schools and pupils from the relatively low social status schools showed about the same gain.
4) Grade and social status were not related to the amount of improvement but were related to the level of performance.
5) The tests were significantly related to intelligence.

Atkin (1961) investigated children's reactions to the study of certain science topics deemed basic to modern astronomy by the professional research astronomer. Pupils in Grades 4, 5 and 6 with IQ's over 105 were used in this study to provide fast feedback on the assumption that if the bright children could not grasp the concepts involved it was unlikely that children of average ability would be able to understand them. Also, the bright children provided a source of novel ideas for teaching approaches to the new content. He concluded that the children's interest was high and that they were able to learn astronomy concepts deemed fundamental to the science even if these concepts were not perceived as closely related to their personal and social needs.

In a two phase study, McNeil and Keislar (1962) investigated the readiness of pupils in the lower elementary grades to learn certain abstract concepts related to molecular theory. In the first phase of the study 72 pupils were interviewed to determine their explanations of events related to evaporation and condensation. It was found (p. 154) that "perceptual (direct, sensory) approaches rather than theoretical solutions predominated," that there was specificity in children's causal thinking, and that there was a noteworthy lack of supernatural and animistic forces used in accounting for events.

In the second phase of the study six first grade pupils were selected to be given instruction and six other pupils were selected as controls matched on the basis of sex, intelligence and scientific vocabulary. The instructional materials included 500 picture cards each accompanied by a written passage which was read to the pupils. Evaluation was by multiple-choice response to items depicted in the pictures. McNeil and Keislar found that none of the controls could answer questions dealing with the relation of molecules and states of matter, while the experimental subjects could answer questions which dealt with content similar to that used in the instructional materials but failed to generalize to new situations. They also found that the subjects were able to read and interpret symbolic diagrams, and to use them to arrive at science concepts.

McCombs (1963) studied the problem of identifying basic scientific concepts appropriate for pupils in kindergarten through Grade 3 and to develop experiences which should aid in the development of these concepts. A survey of science textbooks for Grades K-12 led to the identification of three concepts for each of the major science areas for high school. From these, 12 biological and 17 physical science concepts for use in the primary grades were derived. Laboratory experiences were designed to provide pupils with guidance to the understanding of the concepts through experience. Major conclusions were:

1) Development of basic science concepts should be a primary objective of the elementary school.
2) The psychological characteristics of the child should be considered more completely in planning a science program.
3) The child's ability to recognize causal relationships should be developed through appropriate science experiences.
4) Generalizations and concepts should be developed through problem solving and subsequently applied inductively.

Dennis (1966) investigated the lower effective limit below which children could not adequately comprehend selected aspects of the kinetic theory of matter. Approximately 200 pupils in Grades 2-6 were separated into high and low ability groups according to their IQ scores and presented with a series of lessons dealing with three concepts related to the kinetic theory of matter. The lessons were designed to prevent low reading ability from interfering with a pupil's learning of science. In line with this policy, there were no outside written assignments and no outside written material to read, and all laboratory instructions were written in Pittman's Initial Teaching Alphabet (i/t/a). When a new word was mentioned, the word was placed on a felt board. Dennis found that the concepts were not effectively taught to pupils of low ability in the third grade nor to pupils of either low or high ability in the second grade and concluded that these concepts should not be introduced below the high ability third grade level.

EVALUATION OF UNDERSTANDINGS OF CONCEPTS

One of the early studies of evaluation of understandings of concepts was that by Howard (1943) in which he established (p. 2) an operational definition of item complexity as a basis for his investigation:

> It is possible that the mental processes involved in selecting the most appropriate answer may vary from item to item. Some may be more complex than others. For some items the mental processes re-

quire the recall of but one specific bit of information, the answer coming almost automatically, if it is known.... Another item may be much more complex, requiring the recall and interrelating of a considerable web of information....Items may be found that are intermediate....One may then think of the test items as graded along a scale of complexity from those requiring the simplest recall to those requiring the greatest complex of recall and interaction of ideas.

The items of the Cooperative General Science Test, Form 1937, were rated for complexity by three panels of judges. One panel was composed of six experts knowledgeable in science; one panel was composed of six good college sophomore students; and one panel was composed of six poor college sophomore students. Howard found that the items could be reliably placed along a complexity continuum by expert judges and that their judgment appeared to be uninfluenced by item difficulty, independent of the validity of the items as measures of intelligence and independent of the validity of the items as measures of science achievement. As he states (p.43), "Item complexity, judged by experts, is here accepted as a distinct and reliably assessed characteristic of test items."

The items were then grouped according to their complexity into five subtests and administered to 1000 students at six colleges and universities. From this portion of the study Howard determined that there were no significant differences among the tests as measures of either science achievement or mental ability. He concluded (p. 43) that, "Use of complex items does not mean that the students are being 'graded' on the basis of their mental ability."

Scott (1964) investigated the relationship of individual differences in cognitive style with respect to science concept achievement. Each of the 12 teachers participating in the study received two weeks of inquiry training and then developed a concept achievement test of the PCE (Predict, Control, Explain) type devised by Suchman and a series of lessons to be used in the instruction of pupils. Two hundred subjects were selected; 100 in each of the 10-year old and 11-year old ranges. Each age range consisted of 50 children of each sex, and each group was further divided into 25 highs and 25 lows on the basis of concept achievement scores. Inductive reasoning, concept achievement and cognitive style in categorization behavior was measured for each subject. Scott found that:

1) Success on the science concept test could predict success on the inductive reasoning test.
2) Cognitive styles in categorization behavior were dependent on science concept achievement in the 11-year old range and for girls in both ranges.
3) Ten-year old girls made higher scores on inductive reasoning than did 10-year old boys.
4) Among the low groups, 11-year olds had a higher inductive reasoning ability than did 10-year olds, and 11-year old boys exhibited fewer cognitive style labels than did 10-year old boys.

Smith and Victor (1961) attempted to determine if a significant relationship existed between success in understanding generalizations about the topic of light and certain standardized tests of academic achievement and mental ability. The determination of such a relationship was seen as useful in making recommendations for the normative grade placement of the science concepts considered in the study. Grade norms were established by means of the Stanford Achievement tests and the Kuhlmann-Anderson IQ tests. Understanding of particular concepts was measured by the Light Test developed for the study. Concepts and generalizations were selected from texts commonly used in junior and senior high schools and organized into instructional units. The instructional units contained demonstrations and reading materials which were presented to 260 pupils in Grades 4-6. They found three basic patterns of difficulty appeared when the percent of the class answering the item correctly was plotted against grade norms:

1) Pattern One was typical of questions asking for the meaning of a word or requiring pupils to identify the shape of an object.
2) Pattern Two was typical of questions asking for the application of an understanding or concept.
3) Pattern Three was typical of questions where the pupil was required to know the meaning of at least two objects or definitions and to apply this in a complex situation.

In a study somewhat similar to the preceding, Pollach (1963) examined the relationships between tests of intelligence and reading and levels of concept development in terms of a hierarchy of understanding defined as knowledge, comprehension and application. The terms, knowledge, comprehension and application, were operationally defined and tests to measure these factors were developed and validated on the basis of science content presented by means of a film presentation. An experimental group of 117 fifth grade pupils saw the films and was tested while a control group of 50 fifth grade pupils was tested without viewing the films. Major findings were:

1) Difficulties in sorting raised doubts as to the effectiveness of such categorization.
2) The relationships between the tests were of such an order that would cause one to question the validity of the hypothesis that items measuring comprehension and application were indeed measuring different things.
3) There was little evidence to support the hypothesis that abilities measured by the test of application were more related to intelligence than abilities measured by the test of knowledge.
4) There was evidence that knowledge of subject matter was a better predictor of behavior on the test of comprehension or application than test scores in reading or intelligence.

In one of the most comprehensive studies concerned with evaluation of understanding, Kropp and Stoker (1966) undertook to determine the construct validity of the classification scheme presented in the Taxonomy of Educational Objectives, Handbook I: Cognitive Domain. Three questions were considered (p. 164):

1) Can empirical evidence be found to support or refute the imputed hierarchical structure?
2) Can empirical evidence be found to support or refute the imputed generality of the several cognitive processes?
3) Can each level of the structure be explained by more elemental cognitive aptitudes, and, if so, do the combinations or numbers of them change systematically from one level to the next?

Four taxonomy-type tests were constructed for use with pupils in Grades 9-12. The tests involved reading a passage which presented relevant content upon which the test items were based. Each test consisted of six subtests corresponding to the major levels of the taxonomy. The subtests for knowledge, comprehension, application and analysis each consisted of 20 four-choice items while the subtests for Synthesis consisted of five free-response items and the subtests for Evaluation consisted of ten free-response items. The tests were administered to approximately 1600 pupils in each of the four grades in 10 Florida schools. In addition, 37 cognitive aptitude tests were selected for use in the study and administered to approximately 275 pupils from each grade.

From the results of the study it was concluded that:

1) There was a clear tendency for the data to support the imputed hierarchical structure of the taxonomy, indicating that the taxonomy does increase in complexity from Knowledge through Evaluation.
2) The data suggests that scores are probably determined by complex interactions of content and process, rather than by processes that transcend various content materials, suggesting that Application in science may not be identical with Application in mathematics.
3) Some patterns emerged which suggested somewhat systematic changes in factor structure of process levels and grades, but since cognitive factors at each level common to all grades could not be extracted, no definitive statement about them could be made.

While the present study derives foundational background from those investigations in the first of the three foregoing categories, present concern is primarily with levels of understanding achieved by pupils receiving certain instruction. Therefore, this investigation is more closely allied with the studies of the latter types dealing with the appropriateness of concepts and methods of evaluation.

III
PROCEDURE

CONCEPTS

The selection of the concepts from the conceptual scheme--force-- involved the use of the following (complete listings are in the Appendix):

1. eight college physics textbooks,
2. three reference books pertaining to concepts in physics,
3. seven high school physics textbooks,
4. five high school physical science textbooks,
5. eight elementary science series each consisting of six texts for Grades 1-6.

The selected concepts were placed in an ordered sequence based upon the logic of the subject matter content and submitted for evaluation to a physicist and to a panel of eight science educators at the University of Wisconsin. Following the evaluation and pilot testing the sequence and the wording of certain concepts were modified to minimize the difficulty for the pupils.

INSTRUCTION

An instructional unit utilizing demonstration-discussion techniques was developed for presenting each of the selected concepts. Demonstrations, apparatus, films, film clips, key questions, and posters were devised or selected for use in presenting and applying the components of each concept. The order of events within each unit was fixed to ensure that all pupils received comparable instruction.

Teaching periods were of 30 minutes duration with about 25 minutes devoted to direct instruction. The teaching was carried on in one room in which the group of selected pupils from a given grade were assembled. Classes met at a regularly scheduled time each day.

Presentation of the concepts followed an outline written on the chalkboard and utilized demonstrations, discussions, films, and film clips. Demonstrations involved the use of an air track, toy cars and tractor, spring-loaded carts, magnets, balloons, and a Van de Graaff generator. Discussions were guided by questions from the teacher designed to emphasize certain aspects of the concepts. Films were utilized in the presentation of some concepts. Each lesson was terminated with a review of the concept using a concept poster. All teaching was done by the investigator. The lessons are available in Working Paper No. 11 of the Center (Helgeson, 1967).

EVALUATION

Instruments of the paper and pencil multiple response type were developed for use in measuring learner achievement in understanding each of the concepts. The items were designed for use in testing achievement at the knowledge, comprehension and application levels of understanding (Bloom, 1956; Hedges, 1966).

1. Knowledge - requiring that the pupil remember information either by recall or recognition, whether this be knowledge of specifics, of ways and means of dealing with specifics, or of universals and generalities within a field.

2. Comprehension - wherein the pupil is expected to be able to translate information into other words or modes of communication, interpret information such as graphs and pictorial representations, and

to be able to extrapolate, including the making of predictions based on understanding of trends, tendencies and conditions. Included at this level is the ability to apply a generalization when its use has been specified.

3. Application - requires that the pupil be able to select and use the correct generalization in a new situation or problem without being prompted as to which generalization is correct or being shown how it is to be applied in the new situation.

The design of the evaluation instruments made it necessary for the pupils to check each item choice as "Yes" or "No." Because a chance score of 50% correct responses could be attained under these conditions, it was decided following the pilot run to modify the items to require the pupils to select the one best response from among four possible alternatives. The instruments included 15 items per concept; five items were devoted to each of the knowledge, comprehension and application levels. Comprehension and application type items all included the use of diagrams to aid in establishing conditions dissimilar from instructional sequences. Evaluation instruments may also be found in the Working Paper (Helgeson, 1967).

Because testing every day during the pilot study seemed to cause considerable negative reaction among the pupils, it was decided to group the evaluation instruments into three testing units. Pupil achievement was evaluated after teaching the first three concepts, after teaching Concepts 4, 5 and 6, and after teaching the seventh and eighth concepts. Testing took place during the regularly scheduled 30 minute class period. In order to minimize reading difficulty, all directions, descriptions of conditions, items, and responses were read to the pupils by the investigator.

SAMPLE SELECTION

Selection of the school population was based upon the following requirements.

1. Diversity of occupations and socio-economic positions among the adult population in the area from which the sample was to be drawn.
2. Minimum of 75 pupils per grade in Grades 2-6.
3. Random selection of 15 pupils per grade permitted.
4. All selected pupils from a given grade to be assembled and taught at one time.
5. Single room for teaching where equipment could be set up.
6. Thirty minute class periods available.
7. Three weeks permitted for study to be carried out.

A school in midwestern Wisconsin met the foregoing criteria and was selected for this investigation.

It was determined that a minimum of 10 pupils per grade was necessary to provide reliable results. Since the instruction was to be the same for all pupils, any pupil who was absent at any time during the study was to be omitted from the sample. The smallest number of pupils in any grade who were present for the entire study was set as the limit and pupils were randomly excluded from the other grades to yield an equal number of pupils per grade.

Class rosters were obtained for all pupils in Grades 2-6 enrolled in the school. The names of the pupils were arranged in alphabetical order within each grade and assigned numbers in chronological order. A table of random numbers was used to select 15 pupils from each grade for the investigation.

ANALYSIS OF DATA

Data from the investigation were subjected to the following analyses:

1. Reliabilities of the three sections of the test instrument were determined by means of the Generalized Item and Test Analysis Program (Baker, 1966). This computer program utilizes the Hoyt Analysis of Variance procedure in computing the internal consistency reliability. (Reliability coefficients are presented in Helgeson, 1968).

2. Differences among the mean test scores achieved by pupils were tested for significance using one-way analysis of variance techniques with a significance level of .05. Computations were accomplished by means of the ONEWAY 1 computer program (Minich, 1966).

3. Newman-Keuls post-hoc tests were used to determine wherein significant differences occurred.

4. Correlations between test scores and IQ were calculated using the REGEL computer program (Jaffarian, 1966). This program employs the Pearson product-moment method of determining correlation coefficients. Significance tests for the correlation coefficients were executed with a significance level of .05.

ACHIEVEMENT CRITERIA

Test score achievement of the pupils was compared to the following criteria:

1. The mean score achieved by the pupils in any grade was significantly better than chance.
2. At least 50% of the pupils in any grade attained scores at least 15% above chance.

The mean score was determined to be significantly greater than chance when it exceeded the critical value $\bar{X}$, which was calculated by: $\bar{X} = U_c + \frac{Z_{.95}(\sigma_c)}{\sqrt{N}}$ (based on formula for standard score for means, Walker and Lev, 1958), where U_c is the mean of the distribution of means of all possible random samples from a theoretical distribution of random guessing scores, $Z_{.95}$ is the standard score for means with confidence coefficient 0.95, σ_c is the standard deviation of the theoretical distribution of means of random guessing scores, and N is the number of subjects in the sample (calculation of σ_c and U_c based on Gulliksen, 1950).

IV
RESULTS

The results of the investigation will be presented in three sections, 1) the selected concepts in ordered sequence, 2) the final sample, and 3) the results of the testing.

SELECTED CONCEPTS

The concepts selected from within the conceptual scheme force are presented according to the instructional sequence followed in the study.

1. Forces are interactions between material bodies, acting as pushes and pulls, that cause changes in motion.
2. A force acting on a body may cause it to accelerate.
3. Forces have magnitude and direction.
4. The acceleration, or change of motion, of a body is proportional to the magnitude of the force acting upon it.
5. Interactions, or forces, between bodies involve actions and reactions.
6. When all the forces acting on a body are in balance, there is no change in its motion.
7. There are different kinds of forces with different origins, but all originate in matter and act upon matter.
8. Forces can be represented by vectors which can be added, subtracted, or resolved into components.

FINAL SAMPLE

After removing those pupils who were absent at some time during the study and randomly excluding enough others to yield an equal number of pupils per grade, the final sample contained 12 pupils per grade.

RESULTS OF TESTING

The results of the testing program will be presented for the knowledge, comprehension and application levels for each concept.

Concept One

Forces are interactions between material bodies, acting as pushes and pulls, that cause changes in motion.

TABLE 1.
CONCEPT 1. MEAN TEST SCORES ARRANGED BY GRADE LEVEL AND LEVEL OF UNDERSTANDING

Grade	Levels of Understanding		
	Knowledge	Comprehension	Application
2	2.00	1.92	1.50
3	3.08	2.00	2.75
4	2.50	3.33	2.25
5	2.25	3.08	2.50
6	3.08	3.08	2.92

I. It is noted from Table 1 that:
   A. The mean scores were lower at the knowledge level than at the comprehension level for pupils in Grades 4, 5 and 6.
   B. The mean scores were higher at the knowledge level than at the application level for all pupils except those in Grade 5.
   C. The mean scores were higher at the comprehension level than at the application level for all pupils except those in Grade 3.

II. Examination of the results for the knowledge, comprehension and application levels separately revealed the following:

A. Knowledge
No significant differences existed among the mean scores achieved by the pupils in the various grades (Table 2).

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	2.88	1.70	2.54
Within	55	1.69		
Total	59			

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	5.39	3.39	2.54
Within	55	1.59		
Total	59			

B. Comprehension
Significant differences existed among the mean scores achieved by pupils in the various grades (Table 3). The application of post-hoc tests failed to reveal the pairs of means between which significant differences existed (Tables 4 and 5).

C. Application
Significant differences existed among the mean scores achieved by pupils in the various grades (Table 6). The mean score achieved by pupils in Grades 3, 5 and 6 was significantly higher than that achieved by the pupils in Grade 2 (Tables 7 and 8).

TABLE 4
CONCEPT 1. COMPREHENSION. DIFFERENCES BETWEEN MEAN TEST SCORES BY GRADE LEVEL

Grade		2	3	5	6	4
	Means	1.92	2.00	3.08	3.08	3.33
2	1.92	0	.08	1.16	1.16	1.41
3	2.00		0	1.08	1.08	1.33
5	3.08			0	0	.25
6	3.08				0	.25
4	3.33					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,55)	2.84	3.41	3.76	4.00
$q_{.95}(r,55)\sqrt{\frac{MS_{error}}{n}}$	1.02	1.23	1.35	1.44

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	3.69	3.80	2.54
Within	55	.97		
Total	59			

TABLE 7.
CONCEPT 1. APPLICATION. DIFFERENCES BETWEEN MEAN TEST SCORES BY GRADE LEVEL

Grade		2	4	5	3	6
	Means	1.50	2.25	2.50	2.75	2.92
2	1.50	0	.75	1.00*	1.25*	1.42*
4	2.25		0	.25	.50	.67
5	2.50			0	.25	.42
3	2.75				0	.15
6	2.92					0

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

TABLE 8.
CONCEPT 1. APPLICATION. CRITICAL VALUES FOR NEWMAN-KEULS TEST

r	2	3	4	5
q.95 (r,55)	2.84	3.41	3.76	4.00
$q_{.95}(r,55)\sqrt{\frac{MS_{error}}{n}}$	.80	.95	1.05	1.12

III. Significant relationships between test scores and IQ were found at the knowledge level in Grades 4 and 6, and at the comprehension level in Grade 2 (Table 9).

TABLE 9.
CONCEPT 1. RELATIONSHIP BETWEEN PUPIL TEST SCORES AND IQ SCORES ACCORDING TO GRADE LEVEL

Grade	Knowledge	Comprehension	Application
2	-.293	.725*	.293
3	.196	.235	-.163
4	.590*	.404	.501
5	.491	.093	-.148
6	.584*	.452	.431

*Correlation coefficients significant at alpha = .05
Critical value = .576

IV. The mean scores exceed the critical chance score for all grades at all levels except for Grade 2 at the application level (Table 10).

TABLE 10.
CONCEPT 1. COMPARISON OF MEAN TEST SCORES WITH CRITICAL CHANCE SCORE BY GRADE AND LEVEL OF UNDERSTANDING

Grade	Levels of Understanding		
	Knowledge	Comprehension	Application
2	2.00*	1.92*	1.50
3	3.08*	2.00*	2.75*
4	2.50*	3.33*	2.25*
5	2.25*	3.08*	2.50*
6	3.08*	3.08*	2.92*

* Mean scores significantly greater than chance.
Critical value = 1.71

V. At least 50% of the pupils in all classes attained scores at least 15% above chance at all levels of understanding with the exception of Grade 2 at the application level (Table 11).

TABLE 11.
CONCEPT 1. NUMBER AND PERCENT OF PUPILS EARNING SCORES AT LEAST 15 PERCENT ABOVE CHANCE ACCORDING TO GRADE AND LEVEL OF UNDERSTANDING

Grade	Levels of Understanding					
	Knowledge		Comprehension		Application	
	Number of pupils scoring at least 15 percent above chance	Percent of class	Number of pupils scoring at least 15 percent above chance	Percent of class	Number of pupils scoring at least 15 percent above chance	Percent of class
2	7	58	8	67	5	42
3	11	91	7	58	11	91
4	8	67	11	91	10	83
5	9	75	11	91	10	83
6	11	91	12	100	11	91

Number of pupils per grade = 12.

Concept Two

A force acting on a body may cause it to accelerate.

TABLE 12.
CONCEPT 2. MEAN TEST SCORES ARRANGED BY GRADE LEVEL AND LEVEL OF UNDERSTANDING

Grade	Levels of Understanding		
	Knowledge	Comprehension	Application
2	1.83	1.83	1.67
3	2.83	1.83	2.25
4	3.58	3.00	3.42
5	2.75	3.33	2.58
6	3.42	3.33	2.42

I. It is noted from Table 12 that:
   A. The mean scores were higher at the knowledge level than at the comprehension level for pupils in Grades 3, 4 and 6.
   B. The mean scores were higher at the knowledge level than at the application level for pupils in all grades.
   C. The mean scores were higher at the comprehension level than at the application level for pupils in Grades 2, 5 and 6.

II. Examination of the results for the knowledge, comprehension and application levels separately reveals the following:
   A. Knowledge
   Significant differences existed among the mean scores achieved by pupils in the various grades (Table 13).

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	5.69	3.21	2.54
Within	55	1.77		
Total	59			

The mean scores achieved by pupils in Grades 4 and 6 are significantly higher than that achieved by pupils in Grade 2 (Tables 14 and 15).

TABLE 14.
CONCEPT 2. KNOWLEDGE. DIFFERENCES BETWEEN MEAN TEST SCORES BY GRADE LEVEL

Grade		2	5	3	6	4
	Means	1.83	2.75	2.83	3.42	3.58
2	1.83	0	.92	1.00	1.59*	1.75*
5	2.75		0	.08	.67	.83
3	2.83			0	.59	.75
6	3.42				0	.16
4	3.58					0

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

TABLE 15.
CONCEPT 2. KNOWLEDGE. CRITICAL VALUES FOR NEWMAN-KEULS TEST

r	2	3	4	5
$q_{.95}(r,55)$	2.84	3.41	3.76	4.00
$q_{.95}(r,55)\sqrt{\frac{MS_{error}}{n}}$	1.08	1.30	1.43	1.52

   B. Comprehension
   Significant differences existed among the mean scores achieved by pupils in the various grades (Table 16).

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	7.17	3.84	2.54
Within	55	1.87		
Total	59			

The application of post-hoc tests failed to reveal the pairs of means between which significant differences exist (Tables 17 and 18).

TABLE 17.
CONCEPT 2. COMPREHENSION. DIFFERENCES BETWEEN MEAN TEST SCORES BY GRADE LEVEL

Grade		2	3	4	5	6
	Means	1.83	1.83	3.00	3.33	3.33
2	1.83	0	0	1.17	1.50	1.50
3	1.83		0	1.17	1.50	1.50
4	3.00			0	.33	.33
5	3.33				0	0
6	3.33					0

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

TABLE 18.
CONCEPT 2. COMPREHENSION. CRITICAL VALUES FOR NEWMAN-KEULS TEST

r	2	3	4	5
q.95 (r,55)	2.84	3.41	3.76	4.00
q.95 (r,55) $\sqrt{\frac{MS_{error}}{n}}$	1.11	1.33	1.47	1.56

C. Application
Significant differences existed among the mean scores acheived by pupils in the various grades (Table 19).

TABLE 19.
CONCEPT 2. APPLICATION. SUMMARY TABLE FOR THE ANALYSIS OF VARIANCE WITH AN ALPHA OF .05

Source	df	MS	F	F (Critical)
Between Grades	4	4.82	2.95	2.54
Within	55	1.63		
Total	59			

The mean score achieved by pupils in Grade 4 is significantly higher than that achieved by pupils in Grade 2 (Tables 20 and 21).

TABLE 20.
CONCEPT 2. APPLICATION. DIFFERENCES BETWEEN MEAN TEST SCORES BY GRADE LEVEL

Grade		2	3	6	5	4
	Means	1.67	2.25	2.42	2.58	3.42
2	1.67	0	.58	.75	.91	1.75*
3	2.25		0	.17	.33	1.17
6	2.42			0	.16	1.00
5	2.58				0	.84
4	3.42					0

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

TABLE 21.
CONCEPT 2. APPLICATION. CRITICAL VALUES FOR NEWMAN-KEULS TEST

r	2	3	4	5
q.95 (r,55)	2.84	3.41	3.76	4.00
q.95 (r,55) $\sqrt{\frac{MS_{error}}{n}}$	1.05	1.26	1.39	1.48

III. A significant relationship between test scores and IQ was found at the application level for Grade 2 (Table 22).

TABLE 22.
CONCEPT 2. RELATIONSHIP BETWEEN PUPIL TEST SCORES AND IQ SCORES ACCORDING TO GRADE LEVEL

Grade	Knowledge	Comprehension	Application
2	.394	-.329	.580*
3	.402	-.274	-.489
4	.289	.521	.258
5	.307	-.177	.219
6	.412	.312	.027

* Correlation coefficients significant at alpha = .05
Critical value = .576

IV. The mean scores exceeded the critical chance scores for all grades at all levels of understanding except for Grade 2 at the application level (Table 23).

TABLE 23.

CONCEPT 2. COMPARISON OF MEAN TEST SCORES WITH CRITICAL CHANCE SCORE BY GRADE AND LEVEL OF UNDERSTANDING

Grade	Levels of Understanding		
	Knowledge	Comprehension	Application
2	1.83*	1.83*	1.67
3	2.83*	1.83*	2.25*
4	3.58*	3.00*	3.42*
5	2.75*	3.33*	2.58*
6	3.42*	3.33*	2.42*

* Mean scores significantly greater than chance
Critical value = 1.71

V. At least 50 percent of the pupils in all classes attained scores at least 15 percent above chance at all levels of understanding with the exception of Grade 2 at the application level (Table 24).

Concept Three

Forces have magnitude and direction.

TABLE 25.

CONCEPT 3, MEAN TEST SCORES ARRANGED BY GRADE LEVEL AND LEVEL OF UNDERSTANDING

Grade	Levels of Understanding		
	Knowledge	Comprehension	Application
2	2.33	1.92	1.33
3	2.58	3.17	.75
4	2.83	1.83	1.42
5	2.58	2.33	1.58
6	2.75	3.00	2.00

I. It is noted from Table 25 that:

A. The mean scores were higher at the knowledge level than at the comprehension level for all pupils except those in Grades 3 and 6.

B. The mean scores were higher at the knowledge level than at the application level for pupils in all grades.

C. The mean scores were higher at the comprehension level than at the application level for pupils in all grades.

TABLE 24.

CONCEPT 2. NUMBER AND PERCENT OF PUPILS EARNING SCORES AT LEAST 15 PERCENT ABOVE CHANCE ACCORDING TO GRADE AND LEVEL OF UNDERSTANDING

Grade	Levels of Understanding					
	Knowledge		Comprehension		Application	
	Number of pupils scoring at least 15 percent above chance	Percent of class	Number of pupils scoring at least 15 percent above chance	Percent of class	Number of pupils scoring at least 15 percent above chance	Percent of class
2	7	58	8	67	5	42
3	11	91	6	50	8	67
4	12	100	9	75	11	91
5	10	83	12	100	11	91
6	9	75	9	75	10	83

Number of pupils per grade = 12.

II. Examination of the results for the knowledge, comprehension, and application levels separately reveals the following:

A. Knowledge

No significant differences existed among the mean scores achieved by pupils in the various grades (Table 26).

TABLE 26.
CONCEPT 3. KNOWLEDGE. SUMMARY TABLE FOR THE ANALYSIS OF VARIANCE WITH AN ALPHA OF .05

Source	df	MS	F	F (Critical)
Between Grades	4	.44	.36	2.54
Within	55	1.24		
Total	59			

B. Comprehension

Significant differences existed among the mean scores achieved by pupils in the various grades (Table 27).

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	4.48	2.97	2.54
Within	55	1.51		
Total	59			

The application of post-hoc tests failed to reveal the pairs of means between which significant differences exist (Tables 28 and 29).

TABLE 28.
CONCEPT 3. COMPREHENSION. DIFFERENCES BETWEEN MEAN TEST SCORES BY GRADE LEVEL

Grade		4	2	5	6	3
	Means	1.83	1.92	2.33	3.00	3.17
4	1.83	0	.09	.50	1.17	1.34
2	1.92		0	.41	1.08	1.25
5	2.33			0	.67	.84
6	3.00				0	.17
3	3.17					0

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

TABLE 29.
CONCEPT 3. COMPREHENSION. CRITICAL VALUES FOR NEWMAN-KEULS TEST

r	2	3	4	5
$q_{.95}(r,55)$	2.84	3.41	3.76	4.00
$q_{.95}(r,55)\sqrt{\frac{MS_{error}}{n}}$	.99	1.19	1.32	1.40

C. Application

Significant differences existed among the mean scores achieved by pupils in the various grades (Table 30).

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	2.46	2.56	2.54
Within	55	.96		
Total	59			

The mean score achieved by pupils in Grade 6 is significantly higher than that achieved by the pupils in Grade 3 (Tables 31 and 32).

TABLE 31.
CONCEPT 3. APPLICATION. DIFFERENCES BETWEEN MEAN TEST SCORES BY GRADE LEVEL

Grade		3	2	4	5	6
	Means	.75	1.33	1.42	1.58	2.00
3	.75	0	.58	.67	.73	1.25*
2	1.33		0	.09	.25	.67
4	1.42			0	.16	.56
5	1.58				0	.42
6	2.00					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,55)	2.84	3.41	3.76	4.00
$q.95(r,55)\sqrt{\frac{MS_{error}}{n}}$	.80	.95	1.05	1.12

III. A significant relationship between test scores and I.Q. was found at the comprehension level for Grade 6 (Table 33).

IV. The mean scores exceeded the critical chance score for all grades at the knowledge and comprehension levels and for Grade 6 at the application level (Table 34).

TABLE 33.
CONCEPT 3. RELATIONSHIP BETWEEN PUPIL TEST SCORES AND IQ SCORES ACCORDING TO GRADE LEVEL

Grade	Knowledge	Comprehension	Application
2	.064	.384	.181
3	.134	.217	.024
4	.347	-.209	.472
5	-.103	.235	.319
6	.439	.671*	.369

* Correlation coefficients significant at alpha = .05
Critical value = .576

TABLE 34.
CONCEPT 3. COMPARISON OF MEAN TEST SCORES WITH CRITICAL CHANCE SCORE BY GRADE AND LEVEL OF UNDERSTANDING

Grade	Levels of Understanding		
	Knowledge	Comprehension	Application
2	2.33*	1.92*	1.33
3	2.58*	3.17*	.75
4	2.83*	1.83*	1.42
5	2.58*	2.33*	1.58
6	2.75*	3.00*	2.00*

*Mean scores significantly greater than chance.
Critical value = 1.71

V. At least 50 percent of the pupils in all classes attained scores at least 15 percent above chance at all levels of understanding with the exceptions of Grades 2, 3 and 4 at the application level (Table 35).

TABLE 35.
CONCEPT 3. NUMBER AND PERCENT OF PUPILS EARNING SCORES AT LEAST 15 PERCENT ABOVE CHANCE ACCORDING TO GRADE AND LEVEL OF UNDERSTANDING

Grade	Levels of Understanding					
	Knowledge		Comprehension		Application	
	Number of pupils scoring at least 15 percent above chance	Percent of class	Number of pupils scoring at least 15 percent above chance	Percent of class	Number of pupils scoring at least 15 percent above chance	Percent of class
2	9	75	7	58	4	33
3	12	100	11	91	1	8
4	9	75	7	58	4	33
5	11	91	10	83	6	50
6	11	91	9	75	8	67

Number of pupils per grade = 12

Concept Four

The acceleration, or change or motion, of a body is proportional to the magnitude of the force acting upon it.

TABLE 36.
CONCEPT 4. MEAN TEST SCORES ARRANGED BY GRADE LEVEL AND LEVEL OF UNDERSTANDING

Grade	Levels of Understanding		
	Knowledge	Comprehension	Application
2	.92	2.25	1.67
3	1.67	2.42	1.67
4	1.67	3.08	2.00
5	1.92	3.50	2.33
6	2.42	3.58	3.00

I. It is noted from Table 36 that:
   A. The mean scores were lower at the knowledge level than at the comprehension level for pupils in all grades.
   B. The mean scores at the knowledge level were lower than or equal to the mean scores at the application level for pupils in all grades.
   C. The mean scores were higher at the comprehension level than at the application level for pupils in all grades.

II. Examination of the results for the knowledge, comprehension and application levels separately reveals the following:
   A. Knowledge
   No significant differences existed among the mean scores achieved by pupils in the various grades (Table 37).

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	3.53	2.42	2.54
Within	55	1.46		
Total	59			

   B. Comprehension
   Significant differences existed among the mean scores achieved by pupils in the various grades (Table 38).

TABLE 38.
CONCEPT 4. COMPREHENSION. SUMMARY TABLE FOR THE ANALYSIS OF VARIANCE WITH AN ALPHA OF .05

Source	df	MS	F	F (Critical)
Between Grades	4	4.48	3.52	2.54
Within	55	1.27		
Total	59			

The mean scores achieved by the pupils in Grades 5 and 6 were significantly higher than that achieved by the pupils in Grade 2 (Tables 39 and 40).

TABLE 39.
CONCEPT 4. COMPREHENSION. DIFFERENCES BETWEEN MEAN TEST SCORES BY GRADE LEVEL

Grade	Means	2	3	4	5	6
		2.25	2.42	3.08	3.50	3.58
2	2.25	0	.17	.83	1.25*	1.33*
3	2.42		0	.66	1.08	1.16
4	3.08			0	.42	.50
5	3.50				0	.08
6	3.58					0

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

TABLE 40.
CONCEPT 4. COMPREHENSION. CRITICAL VALUES FOR NEWMAN-KEULS TEST

r	2	3	4	5
q.95 (r,55)	2.84	3.41	3.76	4.00
q.95 (r,55) $\sqrt{\frac{MS_{error}}{n}}$	.94	1.13	1.24	1.32

   C. Application
   Significant differences existed among the mean scores achieved by pupils in the various grades (Table 41).

GPO 808-018-6

TABLE 41.
CONCEPT 4. APPLICATION. SUMMARY TABLE FOR THE ANALYSIS OF VARIANCE WITH AN ALPHA OF .05

Source	df	MS	F	F (Critical)
Between Grades	4	3.73	2.93	2.54
Within	55	1.27		
Total	59			

The mean score achieved by the pupils in Grade 6 is significantly higher than those achieved by the pupils in Grades 2 and 4 (Tables 42 and 43).

TABLE 42.
CONCEPT 4. APPLICATION. DIFFERENCES BETWEEN MEAN TEST SCORES BY GRADE LEVEL

Grade	Means	2 1.67	4 1.67	3 2.00	5 2.33	6 3.00
2	1.67	0	0	.33	.66	1.33*
4	1.67		0	.33	.66	1.33*
3	2.00			0	.33	1.00
5	2.33				0	.67
6	3.00					0

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

TABLE 43.
CONCEPT 4. APPLICATION. CRITICAL VALUES FOR NEWMAN-KEULS TEST

r	2	3	4	5
q. 95 (r,55)	2.84	3.41	3.76	4.00
$q_{.95}(r,55)\sqrt{\frac{MS_{error}}{n}}$	.94	1.13	1.24	1.32

III. No significant relationships between test scores and I.Q. are found (Table 44).

TABLE 44.
CONCEPT 4. RELATIONSHIP BETWEEN PUPIL TEST SCORES AND IQ SCORES ACCORDING TO GRADE LEVEL

Grade	Knowledge	Comprehension	Application
2	.201	-.047	.223
3	.443	-.321	.035
4	.471	.005	.018
5	.019	.470	.518
6	.503	.564	.289

*Correlation coefficients significant at alpha = .05
Critical value = .576

IV. The mean scores exceeded the critical chance score for Grades 5 and 6 at the knowledge level, for all grades at the comprehension level, and for Grades 4, 5 and 6 at the application level (Table 45).

TABLE 45
CONCEPT 4. COMPARISON OF MEAN TEST SCORES WITH CRITICAL CHANCE SCORE BY GRADE AND LEVEL OF UNDERSTANDING

Grades	Levels of Understanding Knowledge	 Comprehension	 Application
2	.92	2.25*	1.67
3	1.67	2.42*	1.67
4	1.67	3.08*	2.00*
5	1.92*	3.50*	2.33*
6	2.42*	3.58*	3.00*

*Mean scores significantly greater than chance.
Critical value = 1.71

V. At least 50 percent of the pupils in all classes attained scores at least 15 percent above chance at all levels of understanding with the exception of Grades 2 and 3 at the knowledge level (Table 46).

Concept Five

Interactions, or forces, between bodies involve actions and reactions.

TABLE 46.
CONCEPT 4. NUMBER AND PERCENT OF PUPILS EARNING SCORES AT LEAST 15 PERCENT ABOVE CHANCE ACCORDING TO GRADE AND LEVEL OF UNDERSTANDING

	Levels of Understanding					
	Knowledge		Comprehension		Application	
Grade	Number of pupils scoring at least 15 percent above chance	Percent of class	Number of pupils scoring at least 15 percent above chance	Percent of class	Number of pupils scoring at least 15 percent above chance	Percent of class
2	3	25	9	75	6	50
3	4	33	9	75	8	67
4	6	50	12	100	7	58
5	7	58	12	100	10	83
6	9	75	12	100	11	91

Number of pupils per grade = 12.

TABLE 47.
CONCEPT 5. MEAN TEST SCORES ARRANGED BY GRADE LEVEL AND LEVEL OF UNDERSTANDING

Grades	Levels of Understanding		
	Knowledge	Comprehension	Application
2	1.42	2.17	1.33
3	1.00	2.50	1.50
4	2.42	2.00	1.42
5	1.83	2.83	1.42
6	2.50	2.67	2.50

I. It is noted from Table 47 that:
   A. The mean scores were lower at the knowledge level than at the comprehension level for all pupils except those in Grade 4.
   B. The mean scores were higher at the knowledge level than at the application level for pupils in Grades 2, 4 and 5.
   C. The mean scores were higher at the comprehension level than at the application level for all pupils.

II. Examination of the results for the knowledge, comprehension and application levels separately reveals the following:
   A. Knowledge
   Significant differences existed among the mean scores achieved by pupils in the various grades (Table 48).

TABLE 48.
CONCEPT 5. KNOWLEDGE. SUMMARY TABLE FOR THE ANALYSIS OF VARIANCE WITH AN ALPHA OF .05

Source	df	MS	F	F (Critical)
Between Grades	4	4.96	3.98	2.54
Within	55	1.24		
Total	59			

The mean scores achieved by pupils in Grades 4 and 6 are significantly higher than that achieved by pupils in Grade 2 (Tables 49 and 50).

TABLE 49.
CONCEPT 5. KNOWLEDGE. DIFFERENCES BETWEEN MEAN TEST SCORES BY GRADE LEVEL

Grade		3	2	5	4	6
	Means	1.00	1.42	1.83	2.42	2.50
3	1.00	0	.42	.83	1.42*	1.50*
2	1.42		0	.41	1.00	1.08
5	1.83			0	.59	.67
4	2.42				0	.08
6	2.50					0

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

TABLE 50.
CONCEPT 5. KNOWLEDGE. CRITICAL VALUES FOR NEWMAN-KEULS TEST

r	2	3	4	5
q.95 (r,55)	2.84	3.41	3.76	4.00
q.95 (r,55) $\sqrt{\frac{MS_{error}}{n}}$	.91	1.09	1.20	1.28

B. Comprehension
No significant differences existed among the mean scores achieved by the pupils in the various grades (Table 51).

TABLE 51.
CONCEPT 5. COMPREHENSION. SUMMARY TABLE FOR THE ANALYSIS OF VARIANCE WITH AN ALPHA OF .05

Source	df	MS	F	F (Critical)
Between Grades	4	1.43	1.55	2.54
Within	55	.93		
Total	59			

C. Application
Significant differences existed among the mean scores achieved by the pupils in the various grades (Table 52).

TABLE 52.
CONCEPT 5. APPLICATION. SUMMARY TABLE FOR THE ANALYSIS OF VARIANCE WITH AN ALPHA OF .05

Source	df	MS	F	F (Critical)
Between Grades	4	2.86	3.53	2.54
Within	55	.81		
Total	59			

The mean score achieved by pupils in Grade 6 is significantly higher than those achieved by pupils in the other grades (Tables 53 and 54).

TABLE 53.
CONCEPT 5. APPLICATION. DIFFERENCES BETWEEN MEAN TEST SCORES BY GRADE LEVEL.

Grade		2	4	5	3	6
	Means	1.33	1.42	1.42	1.50	2.50
2	1.33	0	.09	.09	.67	1.67*
4	1.42		0	0	.08	1.08*
5	1.42			0	.08	1.08*
3	1.50				0	1.00*
6	2.50					0

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

TABLE 54.
CONCEPT 5. APPLICATION. CRITICAL VALUES FOR NEWMAN-KEULS TEST

r	2	3	4	5
q.95 (r,55)	2.84	3.41	3.76	4.00
q.95 (r,55) $\sqrt{\frac{MS_{error}}{n}}$	.74	.89	.98	1.04

III. A significant relationship between test scores and I.Q. is found at the knowledge level in Grade 6 (Table 55).

TABLE 55.
CONCEPT 5. RELATIONSHIP BETWEEN PUPIL TEST SCORES AND IQ SCORES ACCORDING TO GRADE LEVEL

Grade	Knowledge	Comprehension	Application
2	.334	.380	.207
3	-.101	.300	.286
4	.493	.347	.513
5	.330	.402	.284
6	.773*	-.117	.301

*Correlation coefficients significant at alpha = .05
Critical value = .576

IV. The mean scores exceeded the critical chance score for Grades 4, 5 and 6 at the knowledge level, for all grades at the comprehension level, and for only Grade 6 at the application level (Table 56).

TABLE 56.
CONCEPT 5. COMPARISON OF MEAN TEST SCORES WITH CRITICAL CHANCE SCORE BY GRADE AND LEVEL OF UNDERSTANDING

Grade	Levels of Understanding		
	Knowledge	Comprehension	Application
2	1.42	2.17*	1.33
3	1.00	2.50*	1.50
4	2.42*	2.00*	1.42
5	1.83*	2.83*	1.42
6	2.50*	2.67*	2.50*

*Mean scores significantly greater than chance
Critical value = 1.71

V. At least 50 percent of the class attained scores at least 15 percent above chance in Grades 4, 5 and 6 at the knowledge level, in all grades at the comprehension level, and only in Grade 6 at the application level (Table 57).

Concept Six

When all the forces acting on a body are in balance, there is no change in its motion.

TABLE 58.
CONCEPT 6. MEAN TEST SCORES ARRANGED BY GRADE LEVEL AND LEVEL OF UNDERSTANDING

Grade	Levels of Understanding		
	Knowledge	Comprehension	Application
2	2.08	1.50	.83
3	2.50	1.67	1.42
4	3.42	1.67	2.75
5	3.08	2.75	2.42
6	3.42	2.75	3.42

I. It is noted from Table 58 that:

A. The mean scores were higher at the knowledge level than at the comprehension level for all pupils.

B. The mean scores were higher at the knowledge level than at the application level for all pupils except those in Grade 6 where the mean scores were the same.

C. The mean scores were higher at the comprehension level than at the application level for all pupils except those in Grades 4 and 6.

TABLE 57.
CONCEPT 5. NUMBER AND PERCENT OF PUPILS EARNING SCORES AT LEAST 15 PERCENT ABOVE CHANCE ACCORDING TO GRADE AND LEVEL OF UNDERSTANDING

Grade	Levels of Understanding					
	Knowledge		Comprehension		Application	
	Number of pupils scoring at least 15 percent above chance	Percent of class	Number of pupils scoring at least 15 percent above chance	Percent of class	Number of pupils scoring at least 15 percent above chance	Percent of class
2	4	33	8	67	5	42
3	3	25	11	91	5	42
4	9	75	9	75	3	25
5	7	58	11	91	3	25
6	9	75	11	91	11	91

Number of pupils per grade = 12.

II. Examination of the results for the knowledge, comprehension and application levels separately reveals the following:

A. Knowledge
Significant differences existed among the mean scores achieved by pupils in the various grades (Table 59).

TABLE 59.
CONCEPT 6. KNOWLEDGE. SUMMARY TABLE FOR THE ANALYSIS OF VARIANCE WITH AN ALPHA OF .05

Source	df	MS	F	F (Critical)
Between Grades	4	4.18	2.85	2.54
Within	55	1.47		
Total	59			

The application of post-hoc tests failed to reveal the pairs of means between which significant differences existed (Tables 60 and 61).

TABLE 60.
CONCEPT 6. KNOWLEDGE. DIFFERENCES BETWEEN MEAN TEST SCORES BY GRADE LEVEL

Grade		2	3	5	4	6
	Means	2.08	2.50	3.08	3.42	3.42
2	2.08	0	.42	1.00	1.34	1.34
3	2.50		0	.58	.92	.92
5	3.08			0	.34	.34
4	3.42				0	0
6	3.42					0

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

TABLE 61.
CONCEPT 6. KNOWLEDGE. CRITICAL VALUES FOR NEWMAN-KEULS TEST

r	2	3	4	5
$q_{.95}(r,55)$	2.84	3.41	3.76	4.00
$q_{.95}(r,55)\sqrt{\frac{MS_{error}}{n}}$	.99	1.19	1.32	1.40

B. Comprehension
Significant differences existed among the mean scores achieved by pupils in the various grades (Table 62).

TABLE 62.
CONCEPT 6. COMPREHENSION. SUMMARY TABLE FOR THE ANALYSIS OF VARIANCE WITH AN ALPHA OF .05

Source	df	MS	F	F (Critical)
Between Grades	4	4.73	3.89	2.54
Within	55	1.22		
Total	59			

The application of post-hoc tests failed to reveal the pairs of means between which significant differences existed (Tables 63 and 64).

TABLE 63.
CONCEPT 6. COMPREHENSION. DIFFERENCES BETWEEN MEAN TEST SCORES BY GRADE LEVEL

Grade		2	3	4	5	6
	Means	1.50	1.67	1.67	2.75	2.75
2	1.50	0	.17	.17	1.25	1.25
3	1.67		0	0	1.08	1.08
4	1.67			0	1.08	1.08
5	2.75				0	0
6	2.75					0

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

TABLE 64.
CONCEPT 6. COMPREHENSION. CRITICAL VALUES FOR NEWMAN-KEULS TEST

r	2	3	4	5
$q_{.95}(r,55)$	2.84	3.41	3.76	4.00
$q_{.95}(r,55)\sqrt{\frac{MS_{error}}{n}}$	.91	1.09	1.20	1.28

C. Application
Significant differences existed among the mean scores achieved by the pupils in the various grades. (Table 65).

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	12.92	10.35	2.54
Within	55	1.25		
Total	59			

The mean scores achieved by the pupils in Grades 4, 5 and 6 are significantly higher than those achieved by the pupils in Grades 2 and 3 (Tables 66 and 67).

TABLE 66.
CONCEPT 6. APPLICATION. DIFFERENCES BETWEEN MEAN TEST SCORES BY GRADE LEVEL

Grade		2	3	5	4	6
	Means	.83	1.42	2.42	2.75	3.42
2	.83	0	.59	1.59*	1.92*	2.59*
3	1.42		0	1.00*	1.33*	2.00*
5	2.42			0	.33	1.00
4	2.75				0	.67
6	3.42					0

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

TABLE 67.
CONCEPT 6. APPLICATION. CRITICAL VALUES FOR NEWMAN-KEULS TEST

r	2	3	4	5
$q_{.95}(r,55)$	2.84	3.41	3.76	4.00
$q_{.95}(r,55)\sqrt{\frac{MS_{error}}{n}}$	.91	1.09	1.20	1.28

III. A significant relationship between test scores and I.Q. is found at the knowledge level in Grade 4 (Table 68).

TABLE 68.
CONCEPT 6. RELATIONSHIP BETWEEN PUPIL TEST SCORES AND IQ SCORES ACCORDING TO GRADE LEVEL

Grade	Knowledge	Comprehension	Application
2	-.025	.265	.296
3	.227	.183	.335
4	.879*	.196	.417
5	-.278	.286	.192
6	-.021	.494	-.027

*Correlation coefficients significant at alpha = .05
Critical value = .576

IV. The mean scores exceeded the critical chance score for all grades at the knowledge level, for Grades 5 and 6 at the comprehension level, and for Grades 4, 5 and 6 at the application level (Table 69).

TABLE 69.
CONCEPT 6. COMPARISON OF MEAN TEST SCORES WITH CRITICAL CHANCE SCORE BY GRADE AND LEVEL OF UNDERSTANDING

Grade	Levels of Understanding		
	Knowledge	Comprehension	Application
2	2.08*	1.50	.83
3	2.50*	1.67	1.42
4	3.42*	1.67	2.75*
5	3.08*	2.75*	2.42*
6	3.42*	2.75*	3.42*

*Mean scores significantly greater than chance
Critical value = 1.71

V. At least 50 percent of all classes attained scores at least 15 percent above chance for all grades at all levels with the exception of Grade 4 at the comprehension level and Grade 2 at the application level (Table 70).

TABLE 70.
CONCEPT 6. NUMBER AND PERCENT OF PUPILS EARNING SCORES AT LEAST 15 PERCENT ABOVE CHANCE ACCORDING TO GRADE AND LEVEL OF UNDERSTANDING

Grade	Levels of Understanding					
	Knowledge		Comprehension		Application	
	Number of pupils scoring at least 15 percent above chance	Percent of class	Number of pupils scoring at least 15 percent above chance	Percent of class	Number of pupils scoring at least 15 percent above chance	Percent of class
2	10	83	6	50	2	17
3	11	91	8	67	6	50
4	11	91	5	42	10	83
5	11	91	11	91	8	67
6	10	83	10	83	12	100

Number of pupils per grade = 12

Concept Seven

There are different kinds of forces with different origins, but all originate in matter and act upon matter.

TABLE 71.
CONCEPT 7. MEAN TEST SCORES ARRANGED BY GRADE LEVEL AND LEVEL OF UNDERSTANDING

Grade	Levels of Understanding		
	Knowledge	Comprehension	Application
2	1.50	1.83	1.08
3	3.08	1.92	1.58
4	2.92	2.17	2.92
5	2.83	1.75	2.92
6	3.17	2.17	3.00

I. It is noted from Table 71 that:

A. The mean scores were higher at the knowledge level than at the comprehension level for all pupils except those in Grade 2.

B. The mean scores were higher at the knowledge level than at the application level for all pupils except those in Grades 4 and 5.

C. The mean scores were lower at the comprehension level than at the application level for all pupils except those in Grades 2 and 3.

II. Examination of the results for the knowledge, comprehension and application levels separately reveals the following:

A. Knowledge
Significant differences existed among the mean scores achieved by pupils in the various grades (Table 72).

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	5.61	3.14	2.54
Within	55	1.78		
Total	59			

The mean scores achieved by the pupils in Grades 3, 4, 5 and 6 are significantly higher than that achieved by the pupils in Grade 2 (Tables 73 and 74).

TABLE 73.
CONCEPT 7. KNOWLEDGE. DIFFERENCES BETWEEN MEAN TEST SCORES BY GRADE LEVEL

Grade		2	5	4	3	6
	Means	1.50	2.83	2.92	3.08	3.17
2	1.50	0	1.33*	1.42*	1.58*	1.67*
5	2.83		0	.09	.25	.34
4	2.92			0	.16	.25
3	3.08				0	.09
6	3.17					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,55)	2.84	3.41	3.76	4.00
$q.95(r,55)\sqrt{\frac{MS_{error}}{n}}$	1.11	1.33	1.47	1.56

B. Comprehension
No significant differences existed among the mean scores achieved by pupils in the various grades (Table 75).

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	.44	.31	2.54
Within	55	1.42		
Total	59			

C. Application
Significant differences existed among the mean scores achieved by the pupils in the various grades (Table 76). The mean scores achieved by the pupils in Grades 4, 5 and 6 are significantly higher than those achieved by the pupils in Grades 2 and 3 (Tables 77 and 78).

TABLE 76.
CONCEPT 7. APPLICATION. SUMMARY TABLE FOR THE ANALYSIS OF VARIANCE WITH AN ALPHA OF .05

Source	df	MS	F	F (Critical)
Between Grades	4	9.73	10.36	2.54
Within	55	.94		
Total	59			

TABLE 77.
CONCEPT 7. APPLICATION. DIFFERENCES BETWEEN MEAN TEST SCORES BY GRADE LEVEL

Grade		2	3	4	5	6
	Means	1.08	1.58	2.92	2.92	3.00
2	1.08	0	.50	1.84*	1.84*	1.92*
3	1.58		0	1.34*	1.34*	1.42*
4	2.92			0	0	.08
5	2.92				0	.08
6	3.00					0

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

TABLE 78.
CONCEPT 7. APPLICATION. CRITICAL VALUES FOR NEWMAN-KEULS TEST

r	2	3	4	5
q.95 (r,55)	2.84	3.41	3.76	4.00
$q.95(r,55)\sqrt{\frac{MS_{error}}{n}}$	.80	.95	1.05	1.12

III. A significant relationship between test scores and I.Q. was found at the application level in Grade 5 (Table 79).

TABLE 79.
CONCEPT 7. RELATIONSHIP BETWEEN PUPIL TEST SCORES AND IQ SCORES ACCORDING TO GRADE LEVEL

Grade	Knowledge	Comprehension	Application
2	.437	.221	.229
3	.123	-.062	.336
4	.562	.330	.439
5	.077	-.197	.583*
6	.507	.203	.478

*Correlation coefficients significant at alpha = .05
Critical value = .576

GPO 808-018-5

IV. The mean scores exceeded the critical chance score for all but Grade 2 at the knowledge level, for all grades at the comprehension level, and for Grades 4, 5 and 6 at the application level (Table 80).

TABLE 80.
CONCEPT 7. COMPARISON OF MEAN TEST SCORES WITH CRITICAL CHANCE SCORE BY GRADE AND LEVEL OF UNDERSTANDING

Grades	Levels of Understanding		
	Knowledge	Comprehension	Application
2	1.50	1.83*	1.08
3	3.08*	1.92*	1.58
4	2.92*	2.17*	2.92*
5	2.83*	1.75*	2.92*
6	3.17*	2.17*	3.00*

*Mean score significantly greater than chance. Critical value = 1.71

V. At least 50 percent of the pupils in all classes attained scores at least 15 percent above chance at all levels of understanding with the exception of Grade 2 at the application level (Table 81).

Concept Eight

Forces can be represented by vectors which can be added, subtracted, or resolved into components.

TABLE 82.
CONCEPT 8. MEAN TEST SCORES ARRANGED BY GRADE LEVEL AND LEVEL OF UNDERSTANDING

Grade	Levels of Understanding		
	Knowledge	Comprehension	Application
2	1.33	2.33	1.42
3	1.50	2.50	1.83
4	1.83	2.75	2.00
5	2.50	3.42	1.75
6	2.08	3.50	2.25

I. It is noted from Table 82 that:

A. The mean scores were lower at the knowledge level than at the comprehension level for all pupils.

B. The mean scores were lower at the knowledge level than at the application level for all pupils except those in Grade 5.

C. The mean scores were higher at the

TABLE 81.

CONCEPT 7. NUMBER AND PERCENT OF PUPILS EARNING SCORES AT LEAST 15 PERCENT ABOVE CHANCE ACCORDING TO GRADE AND LEVEL OF UNDERSTANDING

Grade	Levels of Understanding					
	Knowledge		Comprehension		Application	
	Number of pupils scoring at least 15 percent above chance	Percent of class	Number of pupils scoring at least 15 percent above chance	Percent of class	Number of pupils scoring at least 15 percent above chance	Percent of class
2	6	50	7	58	5	42
3	10	83	7	58	7	58
4	10	83	8	67	12	100
5	11	91	6	50	12	100
6	9	75	8	67	11	91

Number of pupils per grade = 12.

comprehension level than at the application level for all pupils.

II. Examination of the results for the knowledge, comprehension and application levels separately reveals the following:

A. Knowledge
No significant differences existed among the mean scores achieved by pupils in the various grades (Table 83).

TABLE 83.
CONCEPT 8. KNOWLEDGE. SUMMARY TABLE FOR THE ANALYSIS OF VARIANCE WITH AN ALPHA OF .05

Source	df	MS	F	F (Critical)
Between Grades	4	2.60	1.90	2.54
Within	55	1.37		
Total	59			

B. Comprehension
Significant differences existed among the mean scores achieved by pupils in the various grades (Table 84).

TABLE 84.
CONCEPT 8. COMPREHENSION. SUMMARY TABLE FOR THE ANALYSIS OF VARIANCE WITH AN ALPHA OF .05

Source	df	MS	F	F (Critical,
Between Grades	4	3.39	4.07	2.54
Within	55	.83		
Total	59			

The mean scores achieved by pupils in Grades 5 and 6 are significantly higher than those achieved by pupils in Grades 2 and 3 (Tables 85 and 86).

TABLE 85.
CONCEPT 8. COMPREHENSION. DIFFERENCES BETWEEN MEAN TEST SCORES BY GRADE LEVEL

Grade		2	3	4	5	6
	Means	2.33	2.50	2.75	3.42	3.50
2	2.33	0	.17	.42	1.09*	1.17*
3	2.50		0	.25	.92*	1.00*
4	2.75			0	.67	.75
5	3.42				0	.08
6	3.50					0

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

TABLE 86.
CONCEPT 8. COMPREHENSION. CRITICAL VALUES FOR NEWMAN-KEULS TEST

r	2	3	4	5
q.95 (r,55)	2.84	3.41	3.76	4.00
q.95 (r,55) $\sqrt{\frac{MS_{error}}{n}}$	.74	.89	.98	1.04

C. Application
No significant differences existed among the mean scores achieved by pupils in the various grades (Table 87).

TABLE 87.
CONCEPT 8. APPLICATION. SUMMARY TABLE FOR THE ANALYSIS OF VARIANCE WITH AN ALPHA OF .05

Source	df	MS	F	F (Critical)
Between Grades	4	1.14	1.06	2.54
Within	55	1.07		
Total	59			

III. A significant relationship between test scores and I.Q. was found at the comprehension level in Grade 6 (Table 88).

TABLE 88.

CONCEPT 8. RELATIONSHIP BETWEEN PUPIL TEST SCORES AND IQ SCORES ACCORDING TO GRADE LEVEL

Grade	Knowledge	Comprehension	Application
2	.358	.545	-.146
3	.279	-.212	-.268
4	.185	.172	.320
5	.089	-.356	.256
6	.146	.720*	.466

*Correlation coefficients significant at alpha = .05
Critical value = .576

TABLE 89.

CONCEPT 8. COMPARISON OF MEAN TEST SCORES WITH CRITICAL CHANCE SCORE BY GRADE AND LEVEL OF UNDERSTANDING

Grade	Levels of Understanding		
	Knowledge	Comprehension	Application
2	1.33	2.33*	1.42
3	1.50	2.50*	1.83*
4	1.83*	2.75*	2.00*
5	2.50*	3.42*	1.75*
6	2.08*	3.50*	2.25*

*Mean scores significantly greater than chance
Critical Value = 1.71

IV. The mean scores exceeded the critical chance score for all but Grades 2 and 3 at the knowledge level, for all grades at the comprehension level, and for all but Grade 2 at the application level (Table 89).

V. At least 50 percent of the pupils in all classes attained scores at least 15 percent above chance at all levels of understanding with the exception of Grade 2 at the knowledge level (Table 90).

TABLE 90.

CONCEPT 8. NUMBER AND PERCENT OF PUPILS EARNING SCORES AT LEAST 15 PERCENT ABOVE CHANCE ACCORDING TO GRADE AND LEVEL OF UNDERSTANDING

	Levels of Understanding					
	Knowledge		Comprehension		Application	
Grade	Number of pupils scoring at least 15 percent above chance	Percent of class	Number of pupils scoring at least 15 percent above chance	Percent of class	Number of pupils scoring at least 15 percent above chance	Percent of class
2	5	42	10	83	6	50
3	8	67	11	91	7	58
4	7	58	12	100	9	75
5	11	91	11	91	7	58
6	9	75	12	100	9	75

Number of pupils per grade = 12

V
CONCLUSIONS AND IMPLICATIONS

CONCLUSIONS

I. When the criteria, a) the mean score achieved by the pupils in any grade is significantly better than chance, and, b) at least 50% of the pupils in any grade attained scores at least 15% above chance, are applied to the achievement of pupils in Grades 2 through 6 the following conclusions are noted (summary in Table 91).

- A. Knowledge
  1. Pupils in Grade 2 progressed to the knowledge level of understanding with Concepts 1, 2, 3 and 6.
  2. Pupils in Grade 3 progressed to the knowledge level of understanding with Concepts 1, 2, 3, 6 and 7.
  3. Pupils in Grade 4 progressed to the knowledge level of understanding with Concepts 1, 2, 3, 5, 6, 7 and 8.
  4. Pupils in Grade 5 progressed to the knowledge level of understanding with all eight concepts.
  5. Pupils in Grade 6 progressed to the knowledge level of understanding with all eight concepts.
- B. Comprehension
  1. Pupils in Grade 2 progressed to the comprehension level of understanding with Concepts 1, 2, 3, 4, 5, 7 and 8.
  2. Pupils in Grade 3 progressed to the comprehension level of understanding with Concepts 1, 2, 3, 4, 5, 7 and 8.
  3. Pupils in Grade 4 progressed to the comprehension level of understanding with Concepts 1, 2, 3, 4, 5, 7 and 8.
  4. Pupils in Grade 5 progressed to the comprehension level of understanding with all eight concepts.
  5. Pupils in Grade 6 progressed to the comprehension level of understanding with all eight concepts.
- C. Application
  1. Pupils in Grade 2 did not progress to the application level of understanding with any of the eight concepts.
  2. Pupils in Grade 3 progressed to the application level of understanding with Concepts 1, 2 and 8.
  3. Pupils in Grade 4 progressed to the application level of understanding with Concepts 1, 2, 4, 6, 7 and 8.
  4. Pupils in Grade 5 progressed to the application level of understanding with Concepts 1, 2, 4, 6, 7 and 8.
  5. Pupils in Grade 6 progressed to the application level of understanding with all eight concepts.

II. While scattered instances of statistically significant correlations exist between pupil test scores and IQ within grades, there seems to be no definitive correlation between test scores and IQ within any grade level when considering all three levels of understanding.

IMPLICATIONS

I. Concept 1 may be included in the instructional program for pupils in Grades 2-6 when the desired level of mastery is knowledge or comprehension, and for pupils in Grades 3-6 when the desired level is application.

II. Concept 2 may be included in the instructional program for pupils in Grades 2-6 when the desired level of mastery is knowledge or comprehension and for pupils in Grades 3-6 when the desired level is application.

III. Concept 3 may be included in the instructional program for pupils in Grades 2-6 when the desired level of mastery is knowledge or comprehension and for pupils in Grade 6 when the desired level is application.

IV. Concept 4 may be included in the instructional program for pupils in Grades 4-6 when the desired level of mastery is knowledge, comprehension, or application.

V. Concept 5 may be included in the instructional program for pupils in Grades 4-6 when the desired level of mastery is knowledge or comprehension, and for pupils in Grade 6 when the desired level is application.

VI. Concept 6 may be included in the instructional program for pupils in Grades 4-6 when the desired level of mastery is knowledge, comprehension, or application.

VII. Concept 7 may be included in the instructional program for pupils in Grades 3-6 when the desired level of mastery is knowledge or comprehension, and in Grades 4-6 when the desired level of mastery is application.

VIII. Concept 8 may be included in the instructional program for pupils in Grades 3-6 when the desired level of mastery is knowledge, comprehension, or application.

IX. The development of concepts such as 4, 5 and 6 involving magnitudes of forces, action-reaction, and equilibrant forces seem to be the most difficult for pupils in Grades 2-5.

X. Although some significant correlations between pupil test scores and IQ's exist, it seems that IQ within the range of this study is not generally a major factor in the achievement of understanding of these concepts utilizing this method of instruction.

XI. Maturity, as indicated by grade level, appears to be a factor in determining success for these eight concepts, particularly at the higher levels of understanding.

TABLE 91.
CONCEPTS RELATED TO FORCE ACCORDING TO GRADE LEVEL AND LEVEL OF UNDERSTANDING

Level of Understanding	GRADES					Significant Differences	Significant Correlation of IQ with Test Scores
	2	3	4	5	6		
Concept 1. Forces are interactions between material bodies acting as pushes and pulls that cause changes in motion.							
K	*#	*#	*#	*#	*#	n.s.d.	
C	*#	*#	*#	*#	*#	n.s.d. (post-hoc)	2
A		*#	*#	*#	*#	3,5,6>2	
Concept 2. A force acting on a body may cause it to accelerate.							
K	*#	*#	*#	*#	*#	4,6>2	
C	*#	*#	*#	*#	*#	n.s.d. (post-hoc)	
A		*#	*#	*#	*#	4>2	2
Concept 3. Forces have magnitude and direction.							
K	*#	*#	*#	*#	*#	n.s.d.	
C	*#	*#	*#	*#	*#	n.s.d. (post-hoc)	6
A				#	*#	6>3	

* mean score of class significantly greater than chance
\# at least 50 percent of class scored at least 15 percent above chance
n.s.d. no significant difference
K-Knowledge, C-Comprehension, A-Application

TABLE 91. (Continued)

Level of Understanding	GRADES 2	3	4	5	6	Significant Differences	Significant Correlation of IQ with Test Scores
Concept 4.	The acceleration, or change of motion, of a body is proportional to the magnitude of the force acting upon it.						
K			#	*#	*#	n.s.d.	
C	*#	*#	*#	*#	*#	5,6>2	
A	#	#	*#	*#	*#	6>2,4	
Concept 5.	Interactions, or forces, between bodies involve actions and reactions.						
K			*#	*#	*#	4,6>2	6
C	*#	*#	*#	*#	*#	n.s.d.	
A					*#	6>2,3,4,5	
Concept 6.	When all the forces acting on a body are in balance, there is no change in its motion.						
K	*#	*#	*#	*#	*#	n.s.d. (post-hoc)	4
C	#	#		*#	*#	n.s.d. (post-hoc)	
A		#	*#	*#	*#	4,5,6>2,3	
Concept 7.	There are different kinds of forces with different origins, but all originate in matter and act upon matter.						
K	#	*#	*#	*#	*#	3,4,5,6>2	
C	*#	*#	*#	*#	*#	n.s.d.	
A		#	*#	*#	*#	4,5,6>2,3	5
Concept 8.	Forces can be represented by vectors which can be added, subtracted, or resolved into components.						
K		#	*#	*#	*#	n.s.d.	
C	*#	*#	*#	*#	*#	5,6>2,3	6
A	#	*#	*#	*#	*#	n.s.d.	

* mean score of class significantly greater than chance
\# at least 50 percent of class scored at least 15 percent above chance
n.s.d. no significant difference
K-Knowledge, C-Comprehension, A-Application

BOOKS ANALYZED IN SELECTING CONCEPTS

COLLEGE PHYSICS TEXTS

Beiser, Arthur. 1964. The science of physics. Addison-Wesley Publishing Company, Inc., Reading, Mass.

Feynman, Richard P., Robert B. Leighton and Matthew Sands. 1964. The Feynman lectures on physics. Addison-Wesley Publishing Company, Inc., Reading, Mass.

Margenau, Henry and Robert B. Lindsay. 1957. Foundations of physics. McGraw-Hill Book Co., New York.

Rogers, Eric M. 1960. Physics for the enquiring mind. Princeton University Press, Princeton, New Jersey.

Sears, Francis W. and Mark W. Zemansky. 1960. College physics. Addison-Wesley Publishing Company, Inc., Reading, Mass.

Shortley, George and Dudley Williams. 1961. Elements of physics. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Taffel, Alexander. 1965. Physics: its methods and meanings. Allyn and Bacon, Boston, Mass.

White, Harvey E. 1959. Physics: an exact science. D. Van Nostrand, Princeton, New Jersey.

REFERENCE BOOKS

Holton, G. and D. H. R. Roller. 1958. Foundations of physical science. Addison-Wesley Publishing Company, Inc., Reading, Mass.

Jammer, Max. 1957. Concepts of force. Harvard University Press, Cambridge, Mass.

Margenau, Henry. 1950. The nature of physical reality. McGraw-Hill Book Company, New York.

HIGH SCHOOL PHYSICS TEXTS

Benumof, Reuben. 1965. Concepts in physics. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Blackwood, Oswald H., Wilmer B. Herron, and William C. Kelly. 1958. High school physics. Ginn and Company, New York.

Burns, Elmer E., Frank L. Verweibe, Herbert C. Hazel and Gordon E. Van Hoeft. 1954. Physics a basic science. D. Van Nostrand, Princeton, New Jersey.

Castka, Joseph F. and Ralph W. Lefler. 1961. Physics problems. Holt, Rinehart and Winston, Inc., New York.

Dull, Charles E., H. Clark Metcalfe, and John E. Williams. 1964. Modern physics. Holt, Rinehart and Winston, Inc., New York.

Lehrman, Robert L. and Clifford Swartz. 1965. Foundations of physics. Holt, Rinehart and Winston, Inc., New York.

Physical Science Study Committee. 1965. Physics. D. C. Heath, Boston, Mass.

HIGH SCHOOL PHYSICAL SCIENCE TEXTS

Barnard, J. Darrell, Celia Stendler, Benjamin Spock and Lon Edwards. 1962. Science: a key to the future. The Macmillan Company, New York.

Branley, Franklyn M., Milton O. Pella and John Urban. 1965. The physical world. Ginn and Company, New York.

Brooks, William O., George R. Tracy, Harry E. Tropp and Alfred E. Freidl. 1966. Modern physical science. Holt, Rinehart and Winston, Inc., New York.

Cable, E. T., R. W. Getchell, W. H. Kadesch, W. J. Poppy and H. E. Crull. 1959. The physical sciences. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.

Pella, Milton O. and Aubrey G. Wood. 1964. Physical science for progress. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

ELEMENTARY SCIENCE SERIES (PUBLISHERS)

Allyn and Bacon, Inc. 1964. Boston, Mass.

American Book Company. 1965. New York.

D. C. Heath. 1965. Boston, Mass.

Ginn and Company. 1965. Boston, Mass.

Holt, Rinehart and Winston, Inc. 1966. New York.

Laidlaw Brothers. 1966. River Forest, Ill.

Macmillan Company. 1966. New York.

Silver Burdett Company. 1965. Morristown, New Jersey.

GPO 808-018-4

BIBLIOGRAPHY

Atkin, J. Myron. 1961. Teaching concepts of modern astronomy to elementary-school children. Science Education 45: 54-58.

Bailey, Ralph G. 1939. The difficulty level of certain concepts. Science Education 25: 84-89.

Baker, Frank B. 1966. Test analysis program. Laboratory of Experimental Design, University of Wisconsin, Madison.

Bloom, Benjamin S., Editor. 1956. Taxonomy of educational objectives, handbook I: cognitive domain. David McKay Company, Inc., New York.

Bronowski, Jacob. 1955. Science and human values. Harper Torchbooks, revised edition, New York.

Bruner, Jerome S. 1966. Toward a theory of instruction. The Belknap Press of 1966, Harvard University Press, Cambridge.

Burlingame, Mildred. 1963. Some determinants of concept formation. The College Education Record 2: 14-19, University of Idaho.

Conant, James B. 1951. Science and common sense. Yale University Press, Oxford.

Craig, Gerald S. 1927. Certain techniques used in developing a course of study for the Horace Mann Elementary School. Bureau of Publications, Teachers College, Columbia University, New York.

Croxton, W. C. 1936. Pupils ability to generalize. School Science and Mathematics 36: 627-634.

__________. 1955. Needed research in the teaching of elementary science with every teacher a researcher. Science Education 39: 17-21.

Dennis, David M. 1966. The introduction of concepts in kinetic molecular theory to children. Journal of Research in Science Teaching 4: 106-111.

Deutsche, Jean M. 1937. The development of children's concepts of causal relations. The University of Minnesota Press, Minneapolis.

Dewey, John. 1916. Democracy and education. The Macmillan Company, New York.

Downing, E. R. 1907. Nature study course. Nature-Study Review 3: 191-195.

Einstein, Albert and Leopold Infeld. 1938. The evolution of physics. Simon and Schuster, New York.

Elkind, David. 1961. The development of quantitative thinking: A systematic replication of Piaget's studies. The Journal of Genetic Psychology, 98: 37-46.

Gulliksen, Harold. 1950. Theory of mental tests. John Wiley and Sons, New York.

Haupt, George W. 1952. Concepts of magnetism held by elementary school children. Science Education 36: 162-168.

Hedges, William D. 1966. Testing and evaluation for the sciences. Wadsworth Publishing Company, Inc., Belmont, Calif.

Helgeson, Stanley L. 1967. Lesson plans and tests of knowledge, comprehension, and application for instruction in concepts of force, Grades 2-6. Practical Paper No. 4 R & D Center, University of Wisconsin, Madison.

Howard, Frederick T. 1943. Complexity of mental process testing. Bureau of Publications, Teachers College, Columbia University, New York.

Hurd, Paul DeH. 1965. Science teaching for a changing world. Scott Foresman Monographs on Education, Scott Foresman and Company, Chicago.

Inbody, Donald. 1963. Children's understandings of natural phenomena. Science Education, 47: 270-278.

Inhelder, Barbel and Jean Piaget. 1958. The growth of logical thinking from childhood to adolescence. Basic Books, Inc., New York.

Ivany, J. W. George. 1966. Psychological aspects of structure in science. The Science Teacher, 33: 22-26.

Jaffarian, William A. 1966. Correlation-regression program. Unpublished computer program. Scientific Literacy Center, University of Wisconsin, Madison.
Keislar, Evan R. 1962. The learning process and the teaching of science. The Science Teacher, 29: 18-25.
King, W. H. 1964. The development of scientific concepts in children. In Ira F. Gordon (Editor), Human development. Scott, Foresman and Company, Chicago.
Kranzer, Herman C. 1963. Children and their science teachers. Journal of Research in Science Teaching, 1: 177-183.
Kropp, Russell P., and Howard W. Stoker. 1966. The construction and validation of the cognitive processes as described in the taxonomy of education objectives. Institute of Human Learning and Department of Educational Research and Testing. Florida State University, Tallahassee.
Lachman, Sheldon J. 1960. The foundations of science. Vantage Press, New York.
Leonelli, Renato E. 1955. The selection and grade placement of physical science principles in the elementary school curriculum. Science Education, 39: 54-57.
Lovell, Kenneth. 1966. Concepts in mathematics. In Klausmeier, H. J. and C. W. Harris (Eds.), Analysis of Concept Learning. Academic Press, New York.
McCarthy, Francis W. 1952. Age placement of selected science subject matter. Science Education, 36: 253-254.
McCombs, Freda S. 1963. The design of selected science experiences for grades K through 3. Dissertation Abstracts, 25: 6315.
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.
Minich, George M. 1966. One-way analysis of variance - oneway 1. Vol. VI, Sec. 3.3 In User's Manual, University of Wisconsin Computing Center, Madison.
Muller, H. J. 1963. What science is. In G. Levine and O. Thomas (Editors), The scientist vs. the humanist. W. W. Norton and Company, New York.
Nash, Leonard K. 1963. The nature of the natural sciences. Little, Brown and Company, Boston.
National Science Teachers Association. 1964. Theory into action. Washington, D. C.
National Society for the Study of Education. 1932. A program for teaching science. Thirty-first Yearbook, Part I. University of Chicago Press (Distributor), Chicago.
__________. 1947. Science education in American schools. Forty-sixth Yearbook, Part I. University of Chicago Press (Distributor), Chicago.
__________. 1960. Rethinking science education. Fifty-ninth Yearbook, Part I. University of Chicago Press (Distributor), Chicago.
Nelson, Pearl A. 1960. Concepts of light and sound in the intermediate grades. Science Education, 44: 142-146.
Oakes, Mervin E. 1947. Children's explanations of natural phenomena. Bureau of Publications, Teachers College, Columbia University, New York.
Olmsted, Cameron B. 1964. An inventory of information beginning first grade children have concerning certain concepts selected from first grade science textbooks. Dissertation Abstracts, 25: 197.
Oxendine, Herbert G. 1958. The grade placement of the physical science principle "Sound is produced by vibrating material." Science Education, 42: 354-357.
Patton, Alva R. 1962. Science for the non-scientist. Burgess Publishing Company, Minneapolis.
Pella, Milton O. 1966. Concept learning in science. The Science Teacher, 33: 31-34.
Phenix, Philip H. 1956. Key concepts and the crisis in learning. Teachers College Record, 58: 137-143.
Piaget, Jean. 1930. The child's conception of physical causality. Harcourt, Brace and World, Inc., New York.
__________. 1964. Development and learning. Journal of Research in Science Teaching, 2: 176-186.
Pollach, Samuel. 1963. Individual differences in the development of certain science concepts. Dissertation Abstracts, 24: 146.
Read, John G. 1958. Present status and problems of one type of grade-placement research. Science Education, 42: 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: 29.
Roller, Duane H. 1960. The education differences between science and technology. In Science and mathematics: countdown for elementary schools. Frontiers of Science Foundation of Oklahoma, Inc.
Russell, David H. 1956. Children's thinking, Ginn and Company, Waltham, Mass.
Scott, Norval C. 1964. Science concept achievement and cognitive functions. Journal of Research in Science Teaching, 2: 7-16.
Silano, Alfred A. 1952. The spontaneous remarks of children concerning magnetic phenomena.

School Science and Mathematics, 52: 477-482.

Smith, Gary R., and Edward Victor. 1961. Science concepts of light. The Science Teacher, 28: 11-14.

Smith, Herbert A. 1963. Educational research related to science instruction for the elementary and junior high school: a review and commentary. Journal of Research in Science Teaching, 1: 199-225.

Stendler, Celia B. 1962. Elementary teaching and the Piagetian theory. The Science Teacher, 29: 34-39

Underhill, Ora. E. 1941. The origins and development of elementary school science. Scott, Foresman and Company, Chicago.

Waetjen, Walter B. 1965. Learning and motivation: implications for the teaching of science. The Science Teacher, 32: 22-26.

Walker, Helen M., and Joseph Lev. 1958. Elementary statistical methods. Holt, Rinehart and Winston, New York.

Weller, Florence, and Otis W. Caldwell. 1933. The nature study and elementary science movement. School Science and Mathematics, 33: 730-740.

Woodruff, Asahel D. 1964. The use of concepts in teaching and learning. The Journal of Teacher Education, 25: 81-99.

Yuckenberg, Laura M. 1962. Children's understanding of certain concepts of astronomy in the first grade. Science Education, 46: 148-150.

FROM:

ERIC FACI [redacted]

SU TE 601 [redacted]

1735 EYE [redacted]

WASHINGT [redacted]