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THE RELATIVE EFFECTIVENESS OF TWO METHODS OF INSTRUCTION IN TEACHING THE CLASSIFICATIONAL CONCEPTS OF PHYSICAL AND CHEMICAL CHANGE TO ELEMENTARY SCHOOL CHILDREN.

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REPORTED IS THE DETERMINATION OF THE RELATIVE EFFECTIVENESS OF TWO METHODS OF INSTRUCTION IN TEACHING CLASSIFICATIONAL CONCEPTS OF PHYSICAL AND CHEMICAL CHANGE TO ELEMENTARY SCHOOL CHILDREN. THROUGH TEACHER-DIRECTED DEMONSTRATION-DISCUSSION, STUDENTS IN GRADES 2-6 WERE INSTRUCTED IN THE CONCEPTS OF PHYSICAL AND CHEMICAL CHANGE WITH THE RESPONSIBILITY FOR FORMULATING AND STATING THE GENERALIZATION FOR PROPER CLASSIFICATION OF PHENOMENA RESTING WITH THE LEARNER IN ONE TREATMENT AND WITH THE TEACHER IN THE OTHER. CONCLUDED WERE THAT (1) THERE IS NO EFFECT DUE TO TREATMENT, (2) WHEN THE STUDENT'S LEVEL OF UNDERSTANDING OF THE CONCEPTS IS ASSESSED IN TERMS OF HIS ABILITY TO VERBALIZE, MATURATION AS REPRESENTED BY GRADE LEVEL IS A FACTOR, (3) THESE CONCEPTS CAN BE SUCCESSFULLY TAUGHT IN GRADE 6 WHEN THE INSTRUCTIONAL SEQUENCE IS EITHER OF THOSE UTILIZED IN THIS STUDY, (4) I.Q. AND PAST ACHIEVEMENT IN SCIENCE AND MATHEMATICS ARE NOT SIGNIFICANTLY RELATED TO THE ABILITY OF CHILDREN IN GRADES 2-6 TO FORMULATE THE CONCEPTS, AND (5) CHILDREN IN GRADES 2-6 DO NOT UTILIZE THE OPPORTUNITY TO ASK QUESTIONS TO CONFIRM THEIR CONCLUSIONS. (DS)

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WISCONSIN RESEARCH AND DEVELOPMENT

CENTER FOR COGNITIVE LEARNING

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Technical Report No. 39

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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.

Through teacher-directed demonstration-discussion, students in Grades 2–6 were instructed in the concepts of physical and chemical change; responsibility for formulating and stating the generalization for proper classification of phenomena rested with the learner in one treatment and with the teacher in another. It was found children in Grade 6 could learn the concepts under either instructional technique; under some circumstances the concepts could be utilized for instruction in Grades 4 and 5. A finding with implications for classroom instruction in all fields was that these children did not utilize the opportunity to ask questions to confirm their conclusions.

Herbert J. Klausmeier
Director

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ABSTRACT

This study was concerned with determining the relative effectiveness of two methods of instruction in teaching the classificational concepts of physical and chemical change to elementary school children. The subproblems were (1) to determine whether maturity (chronological age) and informal experience, as represented by grade level, contribute to the attainment of a specific level of understanding and (2) to determine what relationship exists between the levels of understanding, IQ, and past achievement in science and mathematics.

Two treatment groups within each of Grades 2–6 formed the 10 instructional units of 10 subjects each. Prior to initiating instruction each student was interviewed to determine whether he possessed the selected concepts of physical and chemical change. The instructional sequence for each treatment group consisted of a lesson approximately 30 minutes in length on each of five consecutive days. The instructional mode was teacher-directed demonstration-discussion. In Treatment 1 the responsibility for formulating the generalization "a reliable criterion for classifying natural phenomena as examples of physical or chemical change is whether or not a new material is formed as a result of the change" was placed on the learner. In Treatment 2 the responsibility for formulating and stating the generalization was accepted by the teachers.

The subjects' understanding was assessed relative to four levels: (1) ability to verbalize the concepts, (2) ability to correctly classify phenomena as examples of physical or chemical change, (3) ability to support correct classifications with correct reasons, and (4) recognition of the need to ask whether or not a new material had been formed as a result of the change when there was no confirmatory evidence that such had occurred.

The evaluation instrument consisted of (1) three oral questions, (2) demonstration of 14 natural phenomena equally divided between physical and chemical changes, and (3) descriptions of six phenomena (three physical and three chemical changes) common to the individual's environmental experience. The test was administered on a clinical basis so that the subject could ask the examiner questions and so that the examiner could determine what criterion the subject was using in classifying each phenomenon. The data were analyzed by analysis of variance, Newman-Keuls post hoc comparison of means, and correlations.

Conclusions regarding the teaching of the classificational concepts of physical and chemical change in Grades 2–6 were: (1) there was no effect due to treatment; (2) when the student's level of understanding of the concepts is assessed in terms of his ability to verbalize, maturation as represented by grade level is a factor; (3) children in Grades 2–6 do not utilize the opportunity to ask questions to confirm their conclusions about the nature of phenomena; (4) these concepts can be successfully taught in Grade 6 when the instructional sequence is either of those utilized in this study; and (5) IQ and past achievement in science and mathematics are not significantly related to the ability of children in Grades 2–6 to formulate these concepts.

I
PROBLEM

INTRODUCTION

As scientists observe and describe nature, they find it necessary to relate the facts that they amass in order to abstract a degree of understanding of the universe. These relationships of facts develop into concepts and, ultimately, into conceptual schemes. Thus, we see that science is an intellectual activity through which man seeks to understand nature.

Concepts are important in science because, through their formation, scientists endeavor to grasp the whole picture from a few small parts. Scientists are at times referred to as "concept builders"; they take observables and form theories to explain their observations. This process of concept building becomes doubly important when we consider that it is essentially the process of education.

In science, concepts are generalizations about the physical or biological world that are accepted by the scholars in the disciplines. To the individual, concepts are mental constructs formulated by the individual. Thus, in the teaching of science we are faced with the problem "what type of approximation will the individual have of a concept that is acceptable to the scientific community?" As evidenced by Russell (1956), concepts become problems when it is mandatory to select the most important ones to learn and the most efficient way to learn them.

THE PROBLEM

To determine the relative effectiveness of two methods of instruction in teaching the classificational concepts of physical and chemical change to elementary school children.

Subproblems to be investigated:

A. To determine whether the maturity of the learner, as represented by grade level, is a factor contributing to the level of understanding of the selected concepts of physical and chemical change achieved by children in Grades 2-6.

B. To determine whether the verbal responses given in support of the classifications of the test phenomena as examples of physical or chemical changes are related to the selected concepts of physical and chemical change.

C. To determine which of the groups, according to treatment and grade level, in Grades 2-6 meet the criterion: 50% or more of the subjects successfully verbalize the selected concepts of physical or chemical change.

D. To determine which of the groups, according to treatment and grade level, in Grades 2-6 meet the criterion: 50% or more of the subjects attain a score of 65% or higher on the classification of natural phenomena as examples of physical or chemical changes.

E. To determine which of the groups, according to treatment and grade level, in Grades 2-6 meet the criterion: 50% or more of the subjects attain a score of 40% or higher in supporting their correct classifications of natural phenomena as examples of physical or chemical changes with correct concepts of physical or chemical change.

F. To determine whether the questions asked by the subjects regarding the physical and chemical change phenomena selected for test items pertain to the selected concepts of physical and chemical change.

G. To determine what relationship exists between the levels of understanding of the concepts of physical and chemical change and certain selected standard achievement levels, following periods of specifically planned instruction.

BACKGROUND OF THE PROBLEM

The issue that the science curriculum should represent a concern for the teaching of concepts and efficient ways to teach them is defensible from the standpoints of A. the nature of science, B. learning theory, C. the relationship between the nature of science and concept formation, and D. the historical development of science education.

A. Nature of Science

The scientific enterprise can be interpreted as consisting of three major subsets. According to the NSTA (1964) these are: (1) the observation and description of nature, (2) trying to understand nature rather than seeking out its detailed structure, and (3) technology. It is obvious that none of these three categories is autonomous; however, the first two aspects will be of paramount importance here.

From the aforementioned aspects, we can conclude that science is an intellectual activity of man. As Roller (1960) has stated, "Science is not concerned with things; it is concerned with ideas, although these ideas often are ideas about things. And those ideas are created by men's minds." Ideas about nature are not inherent in nature; they are man-made impositions on physical reality. Nash (1963) summed it up quite aptly when he referred to science as a way of looking at the world.

Science is thus a human activity by which organized knowledge is acquired about the immediate environment, the earth, and the universe; it is a concept-building enterprise. The activity is spawned by man's insatiable curiosity, his desire to formulate questions and search for their answers. Its roots are imbedded in the observation of nature and various other phenomena. Observations become the facts from which ideas are molded. Ideas are formulated as relationships between two or more facts are sought; they become part of a body of knowledge and, as such, are tools for future use. As the simpler relationships become intertwined with more and more facts and relationships, there develops a need for an explanation that will encompass them all. These formulations become the "best" explanations of all that which has been observed; they are far more powerful than mere descriptions of phenomena.

"That which has been observed" is a crucial phrase here. It is impossible and uneconomical to observe all things. Therefore, the "best" explanations (theories) serve as a medium for grasping an understanding of a whole from a few small pieces. These theories or concepts or conceptual schemes are a unifying structure for all of science. They are an economical means of utilizing the human intellect; they provide for an economy of thought and expression. Bruner (1965) referred to a theory as "an uncanny way of keeping in mind a vast amount while thinking about a very little." And according to Vanderwerf (1961),

> ...one of the greatest pleasures and satisfactions in the study of chemistry is the intellectual game of expanding horizons—of broadening concepts—so that more and more facts and figures can be interpreted, correlated, systematized, and remembered on the basis of fewer and fewer principles.

This statement can be extended to encompass all of science.

In addition to providing for economy, theories serve several other purposes, each in a sense a subset of the concept of economy. They serve to 1. explain the unknown in terms of the known, 2. organize the exponentially growing scientific knowledge into small manageable packages, 3. allow for the incorporation of that which is yet to be observed, and 4. permit prediction. This is but a small sample of the limitless scope of value of these composites of knowledge.

Theories, then, are a major product of science as well as the accumulation of facts and observables; they are pieces of the never-ending body of knowledge which is accumulated through the efforts of mankind. Their strength lies in the fact that they are accepted as tentative; they leave room for modification and refinement as new data become available. Kemeny (1959) stated that the formulation of theories which will explain the facts of the universe becomes the basic purpose of science.

It is evident that science is a vibrant and dynamic intellectual activity of man. It is a cyclic process, for as it strives to simplify that which has been, it opens new frontiers of investigation; it is self-perpetuating; it is a concept-building enterprise.

With science being a concept-building enterprise, the elementary science curriculum should include some of the organizational concepts of science and those responsible for the teaching of science should be concerned with developing efficient means of teaching them.

B. Psychological Considerations

There are two aspects of the learning process meriting attention here. The first of these is the developmental aspect of learning as it relates to the development of the capabilities of the human mind; i.e., readiness. Piaget (1964) proposed "The development of knowledge is a spontaneous process, tied to the whole process of embryogenesis." If this is the case, the learning process is governed by the development of the individual. As the nervous system develops, it reaches a degree of sophistication such that it can go beyond the need for physical stimuli in order to cope with abstractions. Initially, only the simple can be manipulated and at some later date something more complex can be formulated.

Bigge (1964) states that "learning is a change in a living individual which is not heralded by his genetic inheritance. It may be a change in insights, behavior, perception, or a combination of these." This statement, the thesis of the second aspect of learning referred to above, would seem to be in direct contradiction to that of Piaget. Yet, in actuality, they work hand in hand. Piaget inferred that learning occurs only when the mind has developed to the proper level for assimilation. He did not state how much learning can occur, but when it can occur. According to Ausubel, this integration of the development of the nervous system with the experience of the child is the key to learning. He said (1964),

> The intellectual achievement of children can only be accelerated within the limits imposed by the prevailing stage of intellectual development. These limitations cannot be transcended through experience. One can, at best, take advantage of methods that are most appropriate and effective for exploiting the existing degree of readiness.

With learning being a process of gaining or changing insights, outlooks, or thought patterns that is limited to a large degree by the natural ability of the learner, it is necessary to provide a mode of instruction that permits the understandings presently possessed by the individual to interact with new experiences in order that more sophisticated and abstract understandings have the opportunity to emerge. As Gagné (1965) stated, it is the "acquisition of concepts that makes learning possible... the effect of concept learning is to free the individual from control by specific stimuli." Once elementary concepts have been mastered, verbal clues can be utilized to formulate relationships and abstractions.

Bruner (1960) stated that it is "only when basic ideas are put in formalized terms such as equations or elaborated verbal concepts that they are out of the reach of the young child." What the child is expected to learn must be put to him in a form that his stage of development will allow him to pull together into something meaningful. Taba (1965) said,

> Learning is a transactional process. An individual organizes whatever he receives by way of information, from whatever source, according to his current conceptual system. This system may be faulty, partial, productive, or unproductive.

Learning how to formulate ideas and formulating them is critical to the learning process. This point was emphasized by Russell (1956) when he pointed out that the development of these big ideas is very fundamental to any type of subject learning because as a person grows older he usually learns new variations and hierarchies of his old concepts rather than formulating new ones. If this be true, then from the standpoint of learning theory the educative enterprise is obligated to establish concept learning as its basic core. If we accept Einstein's statement (Einstein & Infeld, 1938), and we must, that "physical concepts are free creations of the human mind, and are not, however it may seem, uniquely determined by the external world," then our system of learning must be based on the manner in which concepts are formed. We must teach how concepts are formed and then teach those which have broad and lasting values. The most important facet of any learning, in any subject-matter area, is the development of the ability to use knowledge, not just cover it.

Those persons who are responsible for the teaching of some of the concepts of science should carefully consider the development of the learner when selecting those concepts to be included in the curriculum. The method of instruction, or the form in which the concept to be learned is presented to the learner, may be critical in determining how and when he can learn the selected concept.

C. Science is Concept Formation

Both concept formation and the scientific enterprise are intellectual activities of mankind. The initial step in both processes is to make observations; the origin of thought is concrete experience. These are the facts and percepts that serve as the raw materials for processing. Both rely heavily on the processes of perception, inductive reasoning, and inventiveness. Through the utilization of these processes operating on facts and percepts, descriptions and lesser concepts result. As these simpler ideas are related to each other and more experiences are added, the processing produces tentative theories and more refined concepts. Throughout all this process of refinement, modification proceeds in a manner which permits the incorporation of the new in the absence of many of the facts used to create the original concepts and theories. The simpler concepts are merged into more complex forms; yet, the expressed forms become even more simplified. The net result is an efficient way to acquire understanding and accomplish learning.

Concept formation in the scientific enterprise is a system of organizing knowledge (imposing order) based on observation and experiment. It provides for economy of effort. It provides for freedom of thought and eventually frees us from concrete experiences.

Theories in science are concepts. Because theories in science are creations of the mind having their first origin in encountered experiences, we can teach efficiently from the psychological standpoint and teach the content and the nature of science, simultaneously, by teaching the concepts of science.

In addition, inadequately developed or incorrect concepts or theories have the same origins. These result from a limited opportunity to experience, inadequate and insufficient perceptions, incorrect prior assumptions, incorrect deductions, and the state of the individual involved in the formulation.

To teach concepts then is fruitful in terms of both the processes and the products of science. The processes of concept formation are analogous to the processes of scientific inquiry and discovery, and possession of the concepts represents the knowledge of the theories of science.

Not only would concept learning be advantageous in reference to the nature of science, but it would also do a more complete job of meeting the need of the child to belong and identify. The need to understand the environment would be met by proper selection of experiences to use as the stimuli for formation of concepts. The learning of concepts would thus be seen to be of value by the student if he can be shown how they can be utilized to explain what he has experienced and what he will encounter.

Gagné (1965) has stated that "acquiring the ability to generalize distinguishes concept learning from all other types of learning." In light of the exponential rate at which scientific knowledge (facts and concepts) is being accumulated, we desperately need a powerful educational tool of this type; it is mandatory that we adopt a system of instruction that will assist us in keeping pace with the knowledge explosion while we learn that of value from the past and prepare to deal with the future.

This investigation is concerned with contrasting the understanding of a selected concept that is acquired when the responsibility for formulating the concept is placed on the learner to that where the teacher accepts the responsibility for formulating and stating the concept (generalization).

D. History of Science Education

Evidence that there has been a concern for concept learning in science in the past is quite indirect; inferences can be drawn from statements made, but explicit statements of such purpose in science teaching are very elusive and conspicuously absent. In most statements referral is made to generalizations or understandings which could be considered as concepts as we now know them.

Underhill (1941) wrote that the emphasis in science from 1750—1850 was on a first-hand study of things and phenomena; along with this was a concern for an understanding and an appreciation of science as a way of ascertaining truth and as a method of thought not commonly held. The method approach shows the influence of two early 17th century philosophers, Bacon and Descartes. Educational theories of Comenius, Locke, Rousseau, and Dewey show basic points that lean toward concept learning—true learning comes through experience and it should emphasize understanding. There was a reaction against verbalism. It is possible to extrapolate that "understanding" meant that concepts should be taught and the "method of thought" could be considered a technique of concept learning as well as the activity of the scientific enterprise.

During the period from 1825 to 1860, instructional procedures were often suggested which directed attention toward a more general understanding of the phenomena of nature. From 1860 to 1880, the advocates of Object Teaching emphasized the inductive method with the idea that one should proceed from the simple to the complex and build a hierarchy of concepts; they were concerned with perceptions, conceptualization, and reasoning. Yet, in practice, verbal memorization persisted more strongly than ever. This is not unusual, however, for teachers tend to teach as they were taught.

Between 1870 and 1900, specific school curricula were designed for elementary school science. Parker's curriculum had as one aim an understanding of the universe. Jackman's nature-study curriculum was an example of a program in which the generalizations of science were utilized as the unifying principles. It was also during this period that the Herbartian philosophy directed attention to ideas and their interrelationships (correlational and theoretical concepts). These aims actually become implemented only after Jackman's work. The Harris and Herbartian curricula both emphasized the importance of relationships of ideas in making learning meaningful. Emphasis on ideas and generalizations was also a strong feature of Jackman's program. Even though definite theories of teaching science existed which were similar to the concept learning ideas of the present, and specific curricula were designed to implement these theories, science continued to be taught primarily as a body of knowledge to be passed from one generation to the next. This might be explained in terms of the trend regarding learning theory prevalent during those times. According to Craig (1957),

> Psychological thinking of much of the 19th and 20th centuries was negative about children and tended to place limitations upon their potentialities for growth and development in understanding natural phenomena; many thought science beyond their comprehension.

At present, however, it is quite generally accepted that the interpretation of the physical environment is an integral part of a child's growth and development. In fact, some curriculum designers feel that no scientific thought is beyond the comprehension of the elementary school child.

Another plausible explanation for the failure to teach concepts in a developmental manner is the essentially total absence of research on procedures for developing concepts in science; i.e., concepts to be taught and instructional procedures for teaching them. The value of historical development in teaching science concepts was not realized. Children were not given the opportunity to formulate concepts but, instead, were presented with facts to be memorized and used deductively.

Verbal emphasis on teaching generalizations continued with the publication of the 31st yearbook of the NSSE (1932). However, the impression was given that their list of generalizations represented the ultimate attainable scientific knowledge and as such the generalizations were taught more as facts rather than as a focus for pursuing new frontiers in scientific investigation. The 46th and 59th yearbooks of the NSSE (1947, 1960) restated the need for teaching functional concepts.

Even at present the method of "teaching" concepts as facts to be used deductively is a commonly used pedagogical technique. This is unfortunate, for as Blanc (1967) says,

> Most educators agree that basic generalizations in science cannot be developed without the inductive process of studying concrete situations from which generalized insights emerge. Too often basic generalizations are taught as facts instead of being developed by the children from their own experiences. A real understanding of a generalization is something that must take place within the child's own mind.

It is also possible that what was once referred to as a concept or a generalization may have actually been very factual in reference to what is considered a concept at present.

There was only a minimum of opportunity provided for students to formulate these ideas inductively. In addition, no regard was given to their tentativeness and the probability that they might need revision and modification in the future.

Members of the writing teams of current curriculum projects under the sponsorship of various governmental agencies and private foundations have also expressed a concern for providing instructional programs that aim at teaching concepts and conceptual schemes.

There has been an obvious concern for the teaching of the concepts of science throughout the history of science teaching and in some instances specific references have been made that these concepts should be taught in an inductive manner to be efficiently learned. This study deals with the determination of whether or not one method of instruction is a more efficient way to teach a selected concept than another.

A CONCEPTUAL SCHEMES APPROACH

Though it is quite obvious that those concerned with curriculum planning and development are concerned with the teaching of concepts, and the determination of efficient ways to teach them, a structure for concept selection is not yet established. The crucial problem is that we initially need criteria for selecting those concepts of science that could be included in the curriculum before we can determine how and at what level they should be taught.

The basic assumption made by the Science Concept Group at the R & D Center is that those concepts and/or conceptual schemes which are fundamental to the processing of past experiences from scientific investigation and which serve as focal points for extending the frontiers of science can be arbitrarily classified as classificational, correlational, and theoretical. This assumption is founded upon an examination of the types of things that scientists do with their observations.

It is further assumed that the order of difficulty in teaching selected concepts progresses from the classificational to the theoretical level and that a concept which appears classificational on the surface may have very complex and subtle correlational and theoretical origins and undertones and vice versa. A given concept then may, and usually does, possess traits of all three classes. This assumption of order is based on the amount of immediate concrete experience that is involved as one proceeds from classification to correlation and, ultimately, to theory formation. (There are some concepts which are probably the most useful and important that do not have a direct physical reference; e.g., force, evolution, and particle nature of matter have no observable physical reality. They are known only by their effects or through a process of abstraction.)

Glass (1959) said,

> Concepts and conceptual schemes, though variously defined, are the products of scientific investigation and also serve as the basis for further investigation for the pure scientist and at times become the knowledge that is applied by the applied scientists.

Conant (1947) stated,

> 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.

A major objective of the National Science Teachers Association has been to describe major conceptual schemes that are useful in science curriculum planning; they can be used as criteria for selecting those concepts to be included in the science curriculum. NSTA criteria (1964) for the establishment of these conceptual schemes are the following:

1. The big idea or scheme represents an area in science that has become firmly established in the scientific community and is basic to the progress of research.
2. Each scheme represents a system of facts, principles, and concepts which hopefully can be organized into a sound learning sequence from simple (capable of being taught to very young children) to complex (the level at which "current problems" are being researched).

The basic contention of this organization is that the conceptual schemes approach

> . . . would permit careful consideration of possible experiences to be provided to students at each grade level to extend their understanding of some or all of the schemes; and yet, the packages would not be so all-encompassing as to provide little or no guidance to the science curriculum planner. . . . schemes allow for breadth and depth in the understanding of science.

They provide an opportunity to eliminate isolated, dead-end topics. Each piece is new, but it is related to something else; if raw phenomena cannot be related to first principles, then perhaps something new is needed or the old needs modification. As Craig (1962) has so aptly put it, "The question of how much of the content of science is taught is not of nearly so great importance as is the question of what science content is taught, how it is taught, and the purpose for which it is taught." Because the amount of basic knowledge that can be included in the curriculum is only a minor portion of what is available, the emphasis should be on the selection of those concepts that are most apt to promote the welfare of mankind as well as extend the frontiers of science.

The seventh conceptual scheme of the NSTA has been selected as the central focus for this particular research project. It is formally stated as follows: "All matter exists in time and space and, since interactions occur among its units, matter is subject in some degree to changes with time. Such changes may occur at various rates and in various patterns." Because change is a normal condition in the dynamic continuity in nature with everything in the universe being in a constant state of change, changes of any kind in nature are of interest to the scientist. As stated by Decker (1953),

> The concept of change is one of the most important concepts in science because it is the natural order of events. The child and his environment are in a constant state of change. If a child is to understand himself and the environment in which he lives, he needs to understand the changes within his own body and the changes in the living and nonliving things in his environment. . . . science as a subject is itself in a constant state of change.

Thus, we need to develop science programs that will permit the integration of new and important developments in science as they appear. We need to teach concepts and how they are formed as a natural outgrowth of the scientific enterprise so that this aim can be met.

It is impossible to begin teaching for understanding of the conceptual scheme of change at the level at which it has been stated, but there is little point in developing research that is unrelated to some central issue. Thus, the researcher should at all times "remain aware of the nature of the central problem even though he is working on the fringe [Travers, 1964]." In addition, Bergmann (1957) implied that one should use as a basis for research only those concepts that are linked to other concepts. The concept of change is an integral part of many, if not most, of our scientific concepts; e.g., acceleration, rate, force, equilibrium, and momentum. Another reason for selecting such a high level scheme as a core for research is that it is cross-disciplinary—it gives a unifying thread to all the arbitrarily formed divisions within the whole of science.

CONCEPTS RELATED TO THE CONCEPTUAL SCHEME

The number of "lesser" concepts that are involved in the formation of such an abstract concept (conceptual scheme) as "change" is essentially limitless. A teacher in any one grade can only provide a few activities that will help children formulate concepts that are essential to acquiring an understanding of the major generalization or conceptual scheme. However, as Metcalf (1963) has emphasized, one must take into account William James' Law that "no one sees any further into a generalization than his knowledge of detail extends." To enlarge the understanding of a concept requires that it be taught many times at different levels of abstraction; its acquisition is easiest when familiar and perceptual materials are used whenever possible in its development. The concept may be continually refined as the experience (natural or school-oriented) of the child increases and broadens. The concept may be first encountered at the concrete experience level and then proceed to be refined into a more logical, abstract concept which has more generalizability.

The task of analyzing and organizing a "continuum concept" into a hierarchy of contributing facts, experiences, and ideas which together give it meaning befalls the teacher. It is his or her responsibility to direct the perceptions and develop an instructional sequence of manageable proportions so the concept can be taught in such a manner that the difficulty level(s) may parallel the development of the child.

Within the realm of scientific investigation, information that is steadily amassed needs classification in order to become a great deal more meaningful and useful. Bearing this in mind and examining the conceptual scheme of change, two lesser concepts that can be included in the learning sequence are those of "physical change" and "chemical change." (These concepts are at present commonly included in the elementary-school science curriculum, but there is an absence of research that can serve as a basis for their location in the curriculum and for the determination of a method by which they can be efficiently taught.) The inclusion of these concepts naturally results in a need to develop criteria for classificational purposes. A single criterion was selected for developing this arbitrary classificational system and preparing a sequence of instruction. According to Stendler (1962), "Generally a child classifies on the basis of one criterion; he has trouble with a hierarchial arrangement." The selection of this single criterion was based on consideration of these statements:

> Whenever a process takes place with the production of one or more new materials, the system within which the process takes place is called a chemical system. The process itself within a chemical system is called a chemical change or a chemical reaction. In a chemical reaction, the initial materials (or reactants) are replaced by a new set of materials (or products) [Chemical Bond Approach Project, 1964].

> The characteristics which ALL chemical changes (also called "chemical reactions") have in common are:
> 1. The substances that are present initially (the reactants) disappear.
> 2. One or several new substances (the products) appear as the reaction proceeds and the reactants disappear.
> 3. The properties of the products are recognizably different from those of the reactants.
> 4. Energy in the form of heat, light or electricity is released or absorbed in the course of the chemical change [Grunwald and Johnsen, 1960].

Thus, for the purposes of this study, ***physical change*** is defined as that type of change which ***does not*** result in the formation of a new material and ***chemical change*** is defined as that type of change which ***does*** result in the formation of a new material. ***New material*** is defined as a substance present after the change that was not present prior to the occurrence of the change.

II
REVIEW OF RELATED RESEARCH

THE DEVELOPMENT OF CHILDREN'S CONCEPTS

Although a considerable amount of specific research has been conducted concerning the nature of children's explanations of natural phenomena, the central issue most frequently has been the assessment of the psychological development of the learner rather than the determination of his conceptual understanding of the content of a scientific discipline. When science content (demonstrations, etc.) has been included, it has been utilized primarily as a vehicle for investigating the cognitive development of children.

Some of the earliest investigations pertaining to the characteristics of children's concepts are those that were conducted by Piaget (1929, 1930). These studies tended to focus interest on the psychological aspects of this area as it relates to the understanding of the cognitive development of children.

Piaget utilized an interview technique to determine how the child conceives of himself and of certain natural phenomena. In regard to the natural phenomena, a demonstration was usually performed for the children with the ensuing interview being centered around the observations made by the children.

A major conclusion of Piaget was that general stages of concept formation are characteristic of particular ages and that concepts of a particular kind (e.g., life) evolve in a definite manner. These general stages are: 1. sensory-motor or pre-verbal, 2. pre-operational representation, 3. concrete operations, and 4. formal operations. However, the number of subjects that he relied on and the number of children asked the same questions are not known. With respect to many different concepts, he defined the successive stages through which each concept evolves and linked these with age. He classified concepts of causal relations into 17 different types.

Two different test formats were developed by Deutsche (1937) to examine the development of children's concepts of causal relations. The first consisted of the demonstration of 11 physical phenomena for which the child was asked to give an explanation. The second was composed of 12 verbal questions. These questions were not as varied as those of Piaget. The tests were administered to a population of 732 subjects fairly equally distributed over Grades 3 through 8. The major conclusions were: 1. when all the answers were classified according to Piaget's taxonomy for causal thinking only four types occurred frequently enough to warrant further analysis; 2. no evidence exists that children's reasoning develops by stages; there is a gradual progression in answers with advancing age and all kinds of answers are spread widely over the age range; and 3. evidence was found of specificity in children's causal thinking as opposed to a general level of thinking.

Russell and Dennis (1939) devised a standardized procedure consisting of a questionnaire relating to 20 objects, some physically present, some visible outside the room, and others presented verbally. Criteria were established for classifying answers into the four stages of Piaget and a no-concept stage. The population consisted of 385 subjects ranging from 3 years to 15 years 6 months of age. The results indicated that it is probable that individuals pass sequentially through the stages. However, as also noted by Deutsche, all stages were present at every age instead of being discretely packaged within given age levels.

A clinical study by Huang (1930) was concerned with children's explanations of strange phenomena. These phenomena, which included illustrations and tricks as well as direct problems, were demonstrated to 40 children ranging in age from 4.8 years to 8.11 years and to 11 college girls. The majority of the subjects' explanations indicated possession of naturalistic physical concepts, some very simple. The frequency of occurrence of answers categorized as finalistic, magical, moral, animistic, artificialistic, or mystical causality was slight. The infrequent use of this type of response, in contrast to the findings of Piaget, was postulated to be due to cultural differences between the subjects and an absence of questions pertaining to the stars, winds, etc.

In 1947, Oakes conducted an investigation similar to that of Piaget. He used subjects in Grades K, 2, 4 and 6, the youngest being of age 4 years 10 months. The kindergarten population consisted of 77 subjects; lesser numbers of subjects were used in the other grades. The test consisted of 15 kinds of questions and 17 experiments similar to those of Deutsche. His results led him to agree with Deutsche that the 17 types of explanations of Piaget are not usable. He classified answers as physical or materialistic, nonphysical or nonmaterialistic, and failure to explain. On both types of test items there was a definite increase with age in the frequency of occurrence of physical explanations. In addition, all types of answers were given by all age groups, and each subject gave a wide variety of explanations. There was no evidence for definite stages being characteristic of definite ages. Also, in contrast to Piaget's findings, the bulk of the answers was naturalistic.

Other types of investigations have also created doubt about the existence of definite age stages in concept formation. Welch and Long (1940) gave to subjects whose ages ranged from 42 to 83 months tests that required them to apply concepts which they had previously learned. The number of subjects who passed the tests increased with age, but there was no evidence of definite stages.

The results of studies by Isaacs (1938) and King (1965) are also in contradiction to the findings of Piaget. Both concluded that the definite stages alluded to by Piaget did not exist; however, there was a gradual progression in learning with age with the same child often exhibiting varying types of behavior.

The results of these studies indicate that there should be a concern for the development of the learner as well as the logical structure of the discipline when selecting those science concepts that will be included in the elementary school curriculum. There should be a concern for the manner in which a concept is taught as related to the development of the learner: Is the cognitive structure of the learner developed to a sufficient level that he can learn a given concept and, if so, what is the most efficient way for him to learn a concept at his level of development?

FACTORS AFFECTING THE FORMATION OF CONCEPTS BY CHILDREN

There have been some studies concerned with determining the role that factors such as age and intelligence play in concept formation by children. They indicate that there should be a concern for the maturation of the learner and his experience as represented by his grade level in determining what concepts to include in the elementary school curriculum. These factors determine to some degree what method of instruction is a more efficient means of teaching selected concepts.

Sorting tests were utilized by Reichard, Schneider, & Rapaport (1944) to investigate the abilities of children to formulate concepts. They inferred that there are the concrete level (classification based on nonessential incidental features of the object), the functional level (classification based on use, value, etc.) and the conceptual level (classification based on abstract properties or relations). The functional level was quite typical of children 8—10 years of age. Long and Welch (1942) also found that concepts developed from simple to more complex levels as a function of age.

Deutsche (1937) found little relationship between intelligence test scores and the test scores on causal relations. Long and Welch (1942) reported that chronological age is at least as important as mental age in concept formation.

The studies by Deutsche (1937), Oakes (1947) and Ordan (1945) indicated that variations in experience determine the nature of children's concepts and their use, at least as much as variations in intelligence. Peterson (1932) found that, when subjects were required to formulate generalizations about the principles of the lever, performance was related more closely to grade level than to either age or intelligence.

GRADE-PLACEMENT STUDIES AS A FUNCTION OF FORMAL INSTRUCTION

The amount of research in science education relative to determining where the principles and concepts of science can be taught profitably for the first time in the elementary school is practically nonexistent. Only a few studies have been conducted to determine the grade levels at which various principles, concepts, and percepts may be most readily imparted.

In 1952, McCarthy conducted a study to determine the age placement of certain concepts of work as they are defined in physics. His subjects were primarily from the second grade; however, pupils from Grades K, 1, 3, and 4 were also involved. Prior to instruction he administered a pretest to ascertain the extent of the children's background. The instruction devices consisted of a lever, a pulley, and an inclined plane. Following the manipulation of these devices in experimental situations a test was administered to measure the understanding of selected concepts of work relating to these devices—confirmation of understanding was accomplished by discussion with the subjects. The conclusions drawn were: 1. the influence of mental age on ability to understand these concepts is marked, and 2. the selected concepts of work are suitable for inclusion in the second grade. He further observed that children can often demonstrate an answer on apparatus easier than they can verbalize it.

A study by Reid (1954) was conducted to analyze the understanding of certain atomic energy concepts by students in Grades 4, 5, and 6. A multiple-choice test was used to measure understanding of the selected concepts prior to, and following, instruction. The results showed that children in Grades 4, 5, and 6 made significant gains in understanding following the period of instruction. The groups showed more gain with additional maturity with the Grade 6 population achieving the highest scores.

Read's (1958) analysis of a series of grade-placement studies concerning themselves with physical science principles indicated that maturation was a major factor in the learning of science concepts. He inferred that this maturational advantage was due to the added experiences that are acquired with age.

Evidence concerning the ability of fourth-, fifth-, and sixth-grade children to understand selected concepts related to the kinetic theory of heat was collected by Harris in 1964. The instructional mode was a set of 11 teaching tapes. The evaluation instrument (same for pretest and posttest) was composed of 14 questions administered orally. Certain concepts were found to be appropriate for the fifth and sixth grades whereas most concepts assigned for inclusion in the fourth grade were found to be inappropriate.

One phase of a study by McNeil and Keislar (1962) was devoted to the instruction of a population of six Grade 1 pupils in terms of several molecular concepts. These subjects were of various abilities (based on IQ) and possessed varying degrees of knowledge of science vocabulary. Each subject in the treatment group was paired with a subject in the control group based on sex, IQ, and scientific vocabulary; the control group received no instruction. The instruction consisted of 13 lessons of approximately 15 minutes administered to individual subjects. The evaluation consisted of individually asking each subject to explain examples of the phenomena of condensation and evaporation. None of the subjects in the control group gave explanations pertaining to the interrelationship between molecules and the phases of matter. The subjects from the treatment group gave acceptable explanations for the instances analogous to those in the instruction but they were not able to generalize to unfamiliar situations.

Oxendine (1958) used a population of 700 subjects from Grades 4 and 6 to investigate the grade placement of the concept that "vibration is the source of sound." The mode of instruction was lecture-demonstration. Following the instruction 57% of the subjects in Grade 6 mastered the test, with subjects of mental age 11–12 years also being able to master the test. It was concluded that the fourth-grade subjects were not ready for instruction.

The need for these types of studies has been emphasized by Ausubel (1963). He stated, "We desperately need studies indicating that certain kinds, components and levels of subject matter which cannot be learned efficiently at one age level can be learned efficiently at another age level...." These types of studies also indicated that there must be a concern for the maturation of the learner, as represented by his grade level, in evaluating the relative merits of modes of instruction.

STATUS STUDIES

Studies of this type are concerned with the demonstration of the understandings of concepts and the abilities of students to explain the occurrence of natural phenomena as a function of previous experiences both within and external to the school environment. Their purpose is to determine at what grade level it would be most fruitful to begin instruction aimed at further development of the selected concepts.

One study of this type is that conducted by Haupt (1952) in which he attempted to ascertain the nature of children's previous encounters with the effects of magnetism. He was also concerned with the range of experiences in relation to grade level and age. The 25 subjects in the population (Grades 1–7) were permitted to manipulate two bar magnets, a steel knitting needle, a piece of paper, a splinter of wood and a dip-needle while they were asked questions about some fundamental concepts of magnetism. It was concluded that the children in the lower grades formulate concepts that are as complex and sophisticated as those of the subjects at the higher grade levels.

Inbody (1963) used clinical techniques with 50 kindergarten children to determine their understandings of the occurrence of certain natural phenomena that were discussed as part of the text-centered elementary school curriculum. Twelve phenomena were presented by demonstration, two by pictures, and two by verbal description. The system used for collecting data was to (1) ask the child to predict what would happen to given materials under certain circumstances, (2) ask the child to describe what happened in a particular phenomenon, and (3) ask the child to explain the cause of the occurrence. Inbody concluded that the nature of children's thinking varies with maturity and experience and that the type of instruction that the child can benefit from will be limited by the kind of thinking that the child can do at a given time; children can also understand cause and effect relationships.

A portion of a study by McNeil and Keislar (1962) was devoted to the investigation of the nature of children's explanations for certain natural phenomena. The experimental subjects consisted of 72 randomly selected pupils from the lower elementary grades. These subjects were individually asked questions related to a group of demonstrated phenomena pertaining to condensation and evaporation. The authors found that the explanations were predominantly a description of some feature or aspect of the phenomena. Those explanations which were theoretical in nature were rare; they occurred more frequently in Grade 3 than in Grade 1.

Yuckenberg (1962) examined the nature of certain concepts of astronomy possessed by first-grade children prior to instruction. She was concerned with the nature of their concepts of the sun, moon, day and night, and gravity in order to establish a starting point for continued development of these concepts. A series of ten questions was developed that would tend to draw out the student. The study showed that children possess many concepts that are commonly held by adults and that it is possible to establish a framework of knowledge in the first grade that is essential to developing concepts of astronomy in the later grades.

A study by Young (1958) was concerned with assessing the nature of selected concepts of atomic energy held by children in Grades 3 and 6 prior to instruction. A total of 75 third-grade children was interviewed. The concepts held by 68 children in Grade 6 were identified by use of a questionnaire. Both test instruments contained eight items. The answers were categorized into 3 groups: (1) no answer or a misconception; (2) some information, e.g., atoms are small, round and invisible; and (3) more complete; e.g., all matter is composed of atoms which are, themselves, divisible. The results showed that many children in both groups possessed concepts of atomic structure and the uses of atomic energy. It was also shown that there was an impact due to TV, newspapers, and adult conversation. Many misconceptions also existed.

Silano (1952) used a first- and a third-grade class to determine what information children already possessed concerning concepts of magnetic phenomena and the processes by which children form these concepts. The procedure utilized was to observe the groups of children as they experimented with science principles and apparatus (magnets) and record verbatim the pertinent discussion among the members of the classes. This was followed by a period of free discussion. The conclusions were: (1) younger children are more concerned with "what" happens than with "why" it happens, (2) science instruction in the elementary school should be based on direct experiences, and (3) one can learn what the child is thinking by listening to his free verbal expression.

As pointed out by Inbody (1963), the type of instruction that a child can benefit from will be limited by his maturity, his experience, and the kind of thinking he can do at a given time.

FUTURE RESEARCH IN SCIENCE EDUCATION

If one accepts the assumption that concepts in science can be identified as classificational, correlational, and theoretical, then future research in science education must be concerned with two things.

First, there must be investigations to determine which of the limitless concepts of science can be taught and at what grade levels they can be profitably included. We can no longer include all of the knowledge of science in the curriculum; it has grown beyond the realm of manageable proportions. It will be necessary to establish, through the collection of hard data, which of the organizational concepts in science can be included in the curriculum as well as the most efficient way to teach them.

The second goal of science education research should be to determine which classes of concepts can be taught at various levels in the school environment; e.g., can only classificational concepts be taught in the elementary school or can instructional methods be devised that will allow children to formulate correlational and theoretical concepts?

III
PROCEDURE

INTRODUCTION

The procedures for the pretest-teach-retest sequence employed in this study evolved as a consequence of two pilot studies.

Pilot Study No. 1

Among the methods used were the clinical procedure of testing and the demonstration-discussion procedure of teaching. Both methods functioned satisfactorily with children in Grades 4 through 8 when the concerns in the learning sequence were the concepts of physical and chemical change accepted for this study.

Results from the study indicated that some pupils in Grade 4 were able to learn the accepted concepts of physical and chemical change when given a moderate amount of instruction. These results, coupled with the known variability in abilities at any one grade level, led to the decision to use Grades 3, 4, and 5 as the experimental levels for the second pilot study.

Pilot Study No. 2

The methods utilized in this study were the demonstration-discussion procedure of teaching and the clinical procedure of testing.

Results from this study revealed no significant differences in the abilities of subjects in Grades 3, 4, and 5 to learn the accepted concepts of physical and chemical change when students at each grade level were given identical instruction. These results, coupled with the known variability in abilities at any one grade level, led to the decision to use Grades 2, 3, 4, 5, and 6 for the final study.

The results of this study further indicated that there was a need for additional periods of instruction and that certain pieces of evidence relating to the nature of a change would require visual demonstration rather than only verbal negation. These results were used as guidelines for lengthening and altering the instructional sequence to be used in the final study.

SELECTION OF SAMPLE

The initial population consisted of 265 subjects from two second-, three third-, two fourth-, two fifth-, and two sixth-grade rooms in an elementary school located in a predominantly rural Wisconsin community.

Within each of the five grade levels, the students were randomly assigned to two treatment groups. This procedure produced the 10 groups from which random samples of 10 subjects were selected to produce the final population of 100 subjects.

PRETEST

In order to determine whether or not the pupils in the selected population possessed the desired concepts of physical and chemical change, a pretest consisting of four questions was verbally administered using clinical techniques. The pretest was administered to each of the 265 members of the initial population to insure that any student subsequently randomly selected to receive the final test would also have completed the pretest. The questions and analysis of responses (recorded on tape) were as follows:

Question No. 1: Have you ever heard of the words "physical change" and "chemical change"?

The "yes" and "no" responses were tabulated according to grade level and method of instruction the subjects would later receive.

Questions No. 2 and 3: What do you think happens in a physical change? What do you think happens in a chemical change?

(Results from Pilot Study No. 2 had revealed that it was necessary to pose Questions 2 and 3 even though the response to Question No. 1 had been negative.)

Verbal responses to these two questions were analyzed in terms of the following criteria:

If the subject included one or more of the following items (not necessarily the phraseology) in his description he was classified as having some knowledge of physical change.

1. A physical change has occurred when the form of the substance is changed but the substance itself is the same.
2. In a physical change the substance is changed to another form but you can change it back to its initial form by physical means.
3. A physical change has occurred when the initial substances can be recovered if another physical change occurs.
4. A physical change has occurred when there is any change in the shape of substance but not a change in the substance itself.
5. A physical change only results in a change in appearance.
6. There are no new substances formed when a physical change takes place.

If the subject included one or more of the following items (not necessarily the phraseology) in his description he was classified as possessing some knowledge of chemical change.

1. A chemical change has occurred when two or more substances are mixed together and cannot be separated by physical means.
2. A chemical change has taken place when some or all of the initial materials are no longer present.
3. A chemical change has taken place when a substance is formed that was not one of the initial materials.
4. When a chemical change has taken place it is necessary to have another chemical change in order to recover the initial substances.
5. A chemical change is indicated by the occurrence of certain physical phenomena:
   a. change in color
   b. change in texture
   c. evolution of a gas
   d. formation of a precipitate
   e. release of heat energy
   f. absorption of heat energy
   g. giving off of light
   h. explosions
   i. production of electric current

The responses given to Questions 2 and 3 were treated in the following manner:

1. The responses were classified as acceptable or nonacceptable based on the previously established criteria.
2. Frequency tables were prepared for the acceptable responses by grade level and treatment group.
3. The acceptable responses to Questions 2 and 3 were further examined to determine whether or not the subjects responding possessed the concepts "Physical change is any natural phenomenon which does not result in the formation of a new material" and "Chemical change is any natural phenomenon which results in the formation of a new material." (A new material is understood to be a substance present after the change that was not present prior to the change.)

The responses that included reference to the concepts of physical change and chemical change accepted for this study were tabulated according to grade level and treatment group.

Question No. 4: If you saw a pair of changes and you were told that one was a physical change and one was a chemical change, how would you tell which one was the physical and which one was the chemical change?

The responses given to this question were treated in the following manner:

1. The responses were classified as referring to the concept of "new material" formation or not.
2. Frequency tables for those responses referring to "new material" formation were prepared by grade level and treatment group.

TEACHING SEQUENCE

Within each grade level, the students in the initial population were randomly assigned to two treatment groups. Since a single instructor was to instruct all subjects in a regular classroom setting, it was necessary to conduct the experimental procedures during four consecutive weeks: Week 1—subjects included in Treatment Group No. 1 taught; Week 2—subjects from Treatment Group No. 1 tested; Week 3—subjects in Treatment Group No. 2 taught; and Week 4—subjects from Treatment Group No. 2 tested.

The instructional mode employed was that of teacher-directed demonstration-discussion.

Two methods of instruction were employed in this study. Treatment No. 1 (T1) consisted of an instructional sequence designed to place the responsibility for formulating the generalization "a reliable criterion for classifying changes as examples of physical changes or chemical changes is whether or not a new material results from the change" on the learner. The instructional sequence utilized in Treatment No. 2 (T2) required that the teacher formulate and state the generalization for the learners.

SELECTION OF DEMONSTRATIONS FOR INCLUSIONS IN LESSONS 2, 3, AND 4

Six sets of demonstrations were to be presented (two per lesson) in the three lessons; the sets and their order of presentation would be identical in both treatment groups. All sets of demonstrations included a pair of phenomena chosen on the basis of three criteria:

1. Each pair of demonstrations was to include one physical and one chemical phenomenon.
2. The materials for use in the pairs of demonstrations that were to undergo physical or chemical changes were to be as alike as possible.
3. The number of clues (a clue is defined as a physical phenomenon, such as gas evolution or color change, which is commonly used as an indicator of chemical change) as color, heat and the evolution of a gas, available for use by the subject, that may lead to his making a decision whether the change was physical or chemical was to be at a minimum; one wherever possible. The clue would be present only with the chemical change phenomenon.

In those instances where the clue introduced with the chemical change phenomenon of a given pair could not be visually negated with the physical change phenomenon in another set, a third demonstration was included in the set. This demonstration was a physical change phenomenon accompanied by the same clue as the chemical change phenomenon in the pair.

The format used to guide the subjects in their observations and the later discussion of each demonstrated phenomenon involved four essential steps:

1. Describe the physical properties of the materials before any changes occurred. (To be noted were the similarities and differences between the initial materials to be utilized in each of the individual demonstrations of the pair such that those properties which would be altered during the change would be more readily detectable.)
2. Determine whether or not there were any unusual occurrences during the period when the initial materials were brought into contact or treated in some manner. (The students would be alerted to the necessity of making constant observations.)
3. Compare the properties of the initial and final materials. (Which properties had been altered and to what degree?)
4. Determine whether or not the materials present after the change had occurred were the same kinds as those before the change; i.e., had any "new material" appeared as a result of the change.

As the observations relating to the demonstrations included in a given set were made they were recorded on a student study guide, illustrated on the following page.

The sets of demonstrated phenomena were the following:

Set No. 1

PC: Black paper was torn into strips.
CC: Black paper was torn into strips and burned.
Distractor: Light emission.
Distractor negation: Set No. 2.

STUDENT STUDY GUIDE

	Demonstration # 1	2	3
Physical change	_____	_____	_____
Chemical change	_____	_____	_____
New material	_____	_____	_____
No new material	_____	_____	_____
Other	_____	_____	_____
Light	_____	_____	_____
Electricity	_____	_____	_____
Form	_____	_____	_____
Precipitate	_____	_____	_____
Color	_____	_____	_____
Gas (bubbles)	_____	_____	_____

Set No. 2
PC: A small light bulb was lighted.
CC: A small flashbulb was ignited.
Distractor: Change in form.
Distractor negation: Set No. 1.

Set No. 3
PC: Copper sulfate solution was mixed with water.
CC: Copper sulfate solution was mixed with a solution of barium chloride.
Distractor: Precipitate formation.
Distractor negation: Melted wax was mixed with cold water.

Set No. 4
PC: Acidic phenolphthalein solution was mixed with water.
CC: Acidic phenolphthalein solution was mixed with basic solution.
Distractor: Color change.
Distractor negation: Blue and yellow food dyes were mixed.

Set No. 5
PC: Sugar was dissolved in water.
CC: Alka-seltzer was dropped in water.
Distractor: Gas evolution.
Distractor negation: Charged water was poured into a test tube.

Set No. 6
PC: Glucose was dissolved in water and a conductivity apparatus was immersed in the solution.
CC: Salt was dissolved in water and a conductivity apparatus was immersed in the solution.
Distractor: Conduction or production of electric current.
Distractor negation: Heating a thermocouple connected to a galvanometer.

TREATMENT NO. I

Lesson No. I

Phase one of this lesson was devoted to a discussion of the word "change" as a means of developing the ideas that a single word may have several meanings and that its meaning may be altered by modifiers.

Phase two was concerned with how changes in matter may be detected by comparing the initial properties and states of a material with the properties and states of the materials resulting from the change.

Phase three was directed at the formulation of the generalization that there are many criteria that can be used for classificational purposes.

Phase four of this lesson consisted of a review of the generalizations formulated in Phases two and three.

Lesson No. 2

This lesson included the observation and discussion by the subjects of Sets 1 and 2 of the demonstrated phenomena. Prior to the time the subjects individually observed and discussed the pairs, they were informed that each pair of demonstrations included one physical and one chemical phenomenon.

The teaching procedure employed served as the means of initiating the development of the concepts "a *physical change* occurs when a new material is not formed as a result of change" and "a *chemical change* occurs when a new material is formed as a result of change." Parts of these concepts included were: (1) Physical changes result only in a change in the appearance of the original materials and (2) Chemical changes result in the formation of a new material and the appearance may or may not change. When this discussion progressed to the point that subjects indicated that they recognized that they could classify changes into two groups on the basis of whether or not a new material had been formed, the class labels, physical and chemical change, were supplied. The aspects of the two types of changes were then carefully listed in a review situation.

In all cases the teacher pointed out the clues that could be used that would lead to other observations that were necessary in order to form a valid conclusion regarding the nature of the phenomena which had occurred. However, extreme caution was exercised in making reference to the clues; the discussion emphasized that the clues were not always reliable indicators of certain types of changes and that they should always be used with discretion. (Each of the demonstration sets had been specifically chosen to illustrate that a single clue would not be reliable in every instance; e.g., light emission, color change, etc. may occur with both physical changes and chemical changes.)

Lesson No. 3

Phase No. 1 consisted of a review of the following concepts:

1. Physical changes result only in a change in the appearance of the original materials.
2. Chemical changes result in the formation of a new material and the appearance may or may not change.
3. Certain clues accompanying changes are not reliable indicators of chemical change.

All other instruction procedures were identical to those employed in Lesson No. 2; only Demonstration Sets 3 and 4 were used.

Lesson No. 4

The concepts reviewed were the same as those included in Lesson No. 3. The instructional procedures employed here were identical to those in Lessons 2 and 3 with Demonstration Sets 5 and 6 being utilized in the development of the accepted concepts of physical and chemical change.

Lesson No. 5

This lesson consisted of a student-teacher discussion (review) focused around a series of questions. The six questions posed by the teacher were the following:

1. How can you usually tell when a change has taken place?
2. What are the two types of changes we have discussed?
3. What is the difference between these two types of changes?
4. What types of clues to the nature of the change have we seen?
5. Are the clues reliable?
6. Why aren't the clues reliable?

TREATMENT NO. 2

Lesson No. 1

All phases were identical to those utilized in the instructional sequence used in Treatment No. 1.

Lessons No. 2, 3, 4

All initial phases of discussion and demonstration were identical to those used in Treatment No. 1; however, the observations recorded on the Study Guide were employed to formulate the generalization "there exists a criterion, other than clues, that is a reliable indicator of the nature of a change—whether or not the formation of a new material had resulted from the change." This generalization was expressly formulated and stated by the instructor.

Lesson No. 5

A series of eight questions was posed by the teacher. The first six were the same as those asked in Treatment No. 1. The two additional questions were:

7. What is a sure way to determine the type of change?
8. If the clues are not fully reliable, then why do we use them?

(Special consideration was given to the fact that on the Study Guide "new material" was checked every time there was a chemical change and "no new material" was checked every time there was a physical change.)

FINAL TEST

The week following the instruction of Treatment Group No. 1, and that following the instruction of Treatment Group No. 2, was devoted to testing. A random sample of ten subjects from each of Grades 2, 3, 4, 5, and 6 was selected as the final test group. The 50 subjects tested in a given week were tested randomly to minimize any factor of loss of retention due to time.

All final tests were administered on a clinical basis.

Part One: Verbal Questions

Part one of the test consisted of soliciting a verbal response to each of three questions.

1. Tell me what you think a physical change is.
2. Tell me what you think a chemical change is.
3. How would you tell if a change was a physical change or a chemical change?

Part Two: Demonstrated Phenomena

This portion of the test was also administered on a clinical basis so that an explanation for the classification selected for demonstrated phenomenon could be obtained from each subject and so the subject could ask questions if he wished. The opportunity to ask questions allowed the student to ask whether or not a "new material" had been formed before he submitted his final decision regarding the nature of the change.

Final test demonstrations were presented singly rather than in pairs so that the only information the subject could use in classifying the phenomenon as an example of either a physical change or a chemical change would be the observed changes in the physical characteristics of the materials together with clues and answers to the questions he asked the examiner.

A short explanation of the format of the test was presented to each subject prior to the testing period. The subject was informed that he was going to witness a series of individual demonstrations, that each phenomenon demonstrated would be an example of either a physical or a chemical change, that he would be permitted to ask questions about the individual demonstrations if he wished but that only certain types of questions could and would be answered (the permission to ask questions was included so that a subject who was in doubt concerning the reliability of the clues observed could inquire as to whether a new material had been formed), that he should label each demonstration as an example of a physical change or a chemical change, and that he should verbally explain his basis for making the classification.

All conversation during the testing period was recorded on tape and later analyzed for correctness of classification and nature of the verbal explanations accompanying the classificational answers.

This part of the final test included 14 demonstrations specifically chosen so that: (1) the six clues that had been illustrated in the classroom situations would be represented at least once with a physical change and a chemical change and (2) a novel clue (evolution of heat energy), that had not been illustrated in the classroom situations, would be represented at least once with a physical change and a chemical change. The order of presentation of the demonstrations was random.

Test Demonstrations

1. Chemical change: Magnesium ribbon was burned in air. (Distractors—light emission and change in form.)
2. Chemical change: Baking soda was added to dilute acid. (Distractor—gas evolution.)
3. Physical change: A frosted lightbulb was lighted. (Distractor—light emission.)
4. Physical change: Black ink was added to water until a distinctly black solution resulted. (Distractor—apparent color change.)
5. Chemical change: Solutions of silver nitrate and sodium chloride were mixed. (Distractor—precipitate formation.)
6. Physical change: A magnet was passed through a coil of wire connected to a galvanometer. (Distractor—production of an electric current.)
7. Chemical change: Sugar was heated until it turned brownish-black. (Distractors—change in form and color change.)
8. Physical change: Melted wax was cooled until it solidified. (Distractor—change in form and appearance.)
9. Chemical change: Copper and magnesium-ribbon electrodes connected to a light bulb were immersed in a solution of sulfuric acid. (Distractors—gas evolution, production of electric current and disappearance of the magnesium ribbon.)
10. Physical change: A dry cell was short-circuited with a long copper wire. (Distractor—evolution of heat.)
11. Physical change: A paper towel was crumpled. (Distractor—change in appearance.)
12. Physical change: Water was boiled. (Distractor—gas evolution.)
13. Chemical change: Solutions of ammonium hydroxide and copper sulfate were mixed. (Distractor—color change.)
14. Chemical change: Concentrated solutions of sulfuric acid and sodium hydroxide

were mixed. (Distractors—evolution of heat and gas evolution.)

Part Three: Described Phenomena

The format for administering this part of the test was identical to that for Part Two, except that each phenomenon was described, rather than demonstrated, for the subject by the examiner. It included descriptions of six phenomena common to the individual's environmental experience and it consisted of equal numbers of physical and chemical changes. The order of presentation was random.

Test Descriptions

1. Physical change: Building a house from lumber and other materials.
2. Chemical change: Rusting of iron.
3. Physical change: Melting an icecube.
4. Chemical change: Digestion of food.
5. Chemical change: Growing of plants.
6. Physical change: Formation of a ditch (erosion).

EVALUATION

The data consisting of the scores on the test after instruction were utilized in assessing the student's level of understanding of the selected concepts of physical and chemical change relative to four arbitrary levels.

Level 1: Ability to Verbalize

This level of understanding was said to be achieved by the subject who could verbalize the selected concepts of physical and chemical change (Part one of the test after instruction).

Level 2: Ability to Classify

Evidence of this level of understanding of the selected concepts of physical and chemical change came from the subject's correct classification of demonstrated and described phenomena as examples of physical or chemical changes (Parts two and three of the test after instruction).

Level 3: Ability to Support Correct Classifications with Correct Concepts

The capacity of the subject to correctly classify demonstrated and described phenomena as examples of physical or chemical changes coupled with his ability to support his correct classifications with the proper reasons was evidence of the next level of understanding (Parts two and three of the test after instruction).

Level 4: Recognition of the Need to Ask "the" Question

The highest level of understanding was indicated when the subject recognized the need to ask whether or not a new material had been formed as a result of the change, when there was no confirmatory evidence that such had occurred.

TREATMENT OF DATA

The procedures utilized in the analysis of the data were:

1. Certain portions of the data were tabulated according to grade level of enrollment and treatment.

2. Certain portions of the data were treated utilizing the analysis of variance (ANOVA) techniques.

3. In those instances where a significant F ratio was obtained from the ANOVA, the Newman-Keuls Procedure for the post hoc comparison of means was utilized to determine the source of the significance.

4. The scores earned by the subjects on certain sections of the test after instruction were correlated with each other and with certain selected standard levels of achievement; e.g., IQ.

IV
RESULTS

PRETEST

Results of the pretest, administered to determine which of the subjects possessed the accepted concepts of physical and chemical change prior to instruction, were tabulated according to grade level and treatment.

Question No. 1: Have you ever heard of the words "physical change" and "chemical change"?

Table 1: Number of Subjects Giving an Affirmative Response to Question No. 1, According to Grade Level and Treatment

Grade Level	Treatment[a] 1	2
2	0	2
3	1	2
4	3	4
5	5	2
6	6	6

[a]Maximum cell frequency = 10.

It is noted from Table 1 that the highest frequency of positive response to Question No. 1 occurred in Grade 6 in both treatment groups. Frequencies for Treatment Group No. 1 ranged from 0 in Grade 2 to 6 in Grade 6 with a progressive increase across successive grade levels; for Treatment Group No. 2 frequencies ranged from 2 in Grades 2, 3, and 5 to 6 in Grade 6. There were 31 of the 100 or 31% of the subjects giving an affirmative response to Question No. 1.

Question No. 2: What do you think happens in a physical change?

Analysis of the verbal responses to Question No. 2 (Table 2) resulted in three sixth-grade subjects' responses being classified as indicating the possession of some concept of physical change with two of these three subjects being included in Treatment Group No. 1.

Table 2: Number of Subjects Whose Responses to Question No. 2 Indicated Possession of Some Concept of Physical Change, According to Grade Level and Treatment

Grade Level	Treatment[a] 1	2
2	0	0
3	0	0
4	0	0
5	0	0
6	2	1

[a]Maximum cell frequency = 10.

Question No. 3: What do you think happens in a chemical change?

.able 3: Number of Subjects Whose Responses to Question No. 3 Indicated the Possession of Some Concept of Chemical Change, According to Grade Level and Treatment

Grade Level	Treatment[a] 1	2
2	0	0
3	1	1
4	1	0
5	4	4
6	3	2

[a]Maximum cell frequency = 10.

Table 3 reveals that neither treatment group in the Grade 2 (G2) population nor the G4-T2 group included any subjects whose responses to Question No. 3 indicated that they possessed any concept of chemical change. Each of the treatment groups in the Grade 5 population included four subjects, and the remaining five groups included from one to three subjects, whose responses to Question No. 3 indicated that they possessed some concept of chemical change.

None of the 100 subjects included in the final population possessed the concept of physical change as being that type of change which does not result in the formation of a new material, whereas four of the 100 subjects inferred that their concept of chemical change pertained to the formation of a new material during the change. One of these four subjects was in the G4-T1 group and the remaining three were in the G5-T1 group.

Question No. 4: If you saw a pair of changes and you were told that one was a physical change and one was a chemical change, how would you tell which one was the physical change and which one was the chemical change?

Only one of the 100 subjects (G6-T1 group) in the final population inferred that his criterion for classifying changes as examples of physical changes or chemical changes would be whether or not the change had resulted in the formation of a new material.

Summary

The results of this pretest indicated that, for all practical purposes, the subjects in the final population did not possess the desired concepts of physical and chemical change.

TEST AFTER INSTRUCTION

Part One: Response to Verbal Questions

Question No. 1: What is a physical change? Each subject's response was classified as being acceptable or not acceptable in reference to the concept "Physical change is any natural phenomenon which does not result in the formation of a new material."

The mean scores for acceptable responses to Question No. 1 (Table 4) ranged from 0.300 for the G3-T1 group to 1.000 for the G4-T2 group with mean scores for the five T2 groups being greater than those for the corresponding T1 groups at all but the sixth-grade level where they were identical.

Table 4: Mean Scores for Acceptable Responses to Verbal Question No. 1, According to Grade Level and Treatment [10 subjects per cell; maximum possible mean = 1.000]

Treatment	Grade Level 2	3	4	5	6
1	0.400	0.300	0.500	0.800	0.900
2	0.600	0.600	1.00	0.900	0.900

The verbal responses of 69% of the subjects to Question No. 1 indicated that they possessed the accepted concept of physical change. In each of the T2 groups 60% or more of the subjects indicated that they possessed this concept whereas this same number indicated possession of the concept in only the T1 groups G5 and G6.

Table 5: Summary Table for Analysis of Variance, Question No. 1 [$\alpha = .05$, one-tailed]

Source	df	MS	F	F (Critical)
Methods of instruction	1	1.210	6.76	3.96
Grade level	4	.835	4.66	2.49
Interaction	4	.185	1.03	2.49
Error (within cells)	90	.179		
Total	99			

When these mean scores were subjected to treatment utilizing the analysis of variance technique (Table 5), it was found that:

1. there was a significant difference between the mean scores earned by the pupils receiving different treatments;
2. there was a significant difference between the mean scores earned by the pupils in different grades;
3. there was no significant grade level-treatment interactions.

The mean score (.800) for the T2 population was significantly greater than the mean score (.580) for the T1 population.

Table 6: Tests on differences between all pairs of grade level means. Question No. 1 (Newman-Keuls Procedure)

Grade Level		3	2	4	5	6
	Means	.450	.500	.750	.850	.900
3	.450	-	.050	.300	.400*	.450*
2	.500		-	.250	.350*	.400*
4	.750			-	.100	.150
5	.850				-	.050
6	.900					-
			r = 2	3	4	5
$q_{.95}(r, 90)$			2.82	3.38	3.72	3.95
$q_{.95}(r, 90)\sqrt{MS_{error}/n}$ **			.268	.321	.353	.375

*(p < .05)

**Critical values.

The Newman-Keuls Procedure for post hoc comparison of means was applied to the grade level population mean scores. It is noted from Table 6 that the Grade 5 and 6 populations achieved significantly higher mean scores on Question No. 1 than did the Grade 2 and 3 populations.

Question No. 2: What is a chemical change? Each subject's response was classified as being acceptable or not acceptable in reference to the concept "Chemical change is any natural phenomenon which results in the formation of a new material."

Table 7: Mean Scores for Acceptable Responses to Verbal Question No. 2, Arranged According to Grade Level and Treatment [10 subjects/cell; maximum possible mean = 1.000]

Treatment	Grade Level 2	3	4	5	6
1	0.500	0.300	0.600	0.800	0.900
2	0.600	0.500	1.000	0.900	0.900

The mean scores ranged from 0.300 for the G3-T1 group to 1.000 for the G4-T2 group with mean scores for the T2 group being greater than those for the corresponding T1 groups at all but the sixth grade level where they were identical (Table 7). A total of 70% of the population gave verbal responses which indicated that they possessed the accepted concept of chemical change.

When analysis of variance techniques were applied to these mean scores (Table 8), it was found that:

1. there was no significant difference between the mean scores earned by the pupils receiving different treatments;
2. there was a significant difference between the mean scores earned by the pupils in different grades;
3. there were no significant grade level-treatment interactions.

Table 8: Summary Table for Analysis of Variance, Question No. 2 [$\alpha = .05$, one-tailed]

Source	df	MS	F	F (Critical)
Methods of instruction	1	.640	3.56	3.96
Grade level	4	.925	5.14	2.49
Interaction	4	.115	<1	2.49
Error (within cells)	90	.180		
Totals	99			

Application of the Newman-Keuls Procedure for post hoc comparison of means (Table 9) to the grade level population means

Table 9: Tests on Differences Between All Pairs of Grade Level Means. Question No. 2 (Newman-Keuls Procedure)

Grade Level		3	2	4	5	6
	Means	.300	.500	.600	.800	.900
3	.300	-	.200	.300	.500*	.600*
2	.500		-	.100	.300	.400*
4	.600			-	.200	.300
5	.800				-	.100
6	.900					-
			r = 2	3	4	5
$q_{.95}(r, 90)$			2.82	3.38	3.72	3.95
$q_{.95}(r, 90)\sqrt{MS_{error}/n}$ **			.268	.321	.353	.375

*(p < .05)

**Critical values.

revealed that the Grade 6 population achieved a significantly higher mean score than the Grade 2 and 3 populations and that the Grade 5 population achieved a significantly higher mean score than did the Grade 3 population.

Question No. 3: How would you tell if a change was a physical or a chemical change? A response to this question was considered acceptable if the subject indicated that his criterion for classification was whether or not a "new material" was formed during the change.

Table 10: Mean Scores for Acceptable Responses to Verbal Question No. 3, Arranged by Grade Level and Treatment [10 subjects/cell; maximum possible mean = 1.000]

Treatment	Grade Level 2	3	4	5	6
1	0.300	0.100	0.400	0.300	0.700
2	0.400	0.400	0.500	0.600	0.700

It is noted from Table 10 that the mean scores on Question No. 3 ranged from 0.100 for the G3-T1 group to 0.700 for the G6-T1 and G6-T2 groups, with 50% or more of the subjects in Grades 4, 5, and 6 receiving T2 and the G6-T1 group stating the acceptable criterion for classification of the phenomena. The T2 population achieved a higher mean score than the corresponding T1 population at all grade levels except at Grade 6 where they were identical.

Examining these mean scores with the analysis of variance technique (Table 11) revealed that:

1. there was no significant difference between the mean scores earned by the pupils receiving different treatments;
2. there was no significant difference between the mean scores earned by the pupils in different grades;
3. there were no significant grade level-treatment interactions.

Table 11: Summary Table for the Analysis of Variance, Question No. 3 [α = .05, one-tailed]

Source	df	MS	F	F (Critical)
Methods of instruction	1	.640	2.69	3.96
Grade level	4	.560	2.35	2.49
Interaction	4	.090	<1	2.49
Error (within cells)	90	.238	1	
Totals	99			

The acceptable responses to these three verbal questions were examined to determine what groups in Grades 2–6 met the criterion of 50% or more of the subjects successfully verbalizing the selected concepts of physical and chemical change.

Table 12: Number of Subjects in Each of the 10 Groups Who Successfully Answered the Three Verbal Questions, According to Grade Level and Treatment [Maximum cell frequency = 10]

Question	Grade Level 2 T1	2 T2	3 T1	3 T2	4 T1	4 T2	5 T1	5 T2	6 T1	6 T2
1	4	6	3	6	5	10	8	9	9	9
2	5	6	3	5	6	10	8	9	9	9
3	3	4	1	4	4	5	3	6	7	7

All three verbal questions were successfully answered by 50% or more of the subjects in both treatment groups of the Grade 6 population and the T2 groups of the Grades 4 and 5 populations (Table 12). The desired concept of physical change was verbalized by 50% or more of the subjects in all T2 groups and the Grade 4, 5, and 6 T1 groups; however, only the G3-T1 group had fewer than 50% of its subjects giving the desired concept of chemical change. Question No. 3 was correctly answered by 50% or more of the subjects in both treatment groups of the Grade 6 population and the T2 groups in Grades 4 and 5.

Part Two: Classification of Demonstrated Phenomena

Part two of the final test consisted of demonstrating 14 phenomena, one at a time, to individual subjects. The subject was asked to: (1) classify each phenomenon as a physical or a chemical change and (2) verbally explain the basis for his classification. He was also permitted to ask questions of the examiner about the nature of the phenomena during the testing period. Analysis of the verbal responses will be deferred to a following section of this chapter.

Table 13: Mean Scores Earned on Classification of Demonstrated Phenomena, Arranged According to Treatment and Grade Level [Maximum possible mean = 14]

Treatment	Grade Level 2	3	4	5	6
1	8.200	7.100	9.300	8.700	9.100
2	7.700	8.000	8.7000	8.100	8.400

Table 13 reveals that the mean scores earned on the classification of the 14 demonstrated phenomena ranged from 7.10 for the G3-T1 group to 9.10 for the G6-T1 group with the mean scores for the T1 population being greater than those for the corresponding T2 population at all grade levels except Grade 3.

Table 14: Summary Table for the Analysis of Variance; Classification of Demonstrated Phenomena [$\alpha = .05$, one-tailed]

Source	df	MS	F	F (Critical)
Methods of instruction	1	2.250	<1	3.96
Grade level	4	6.915	2.14	2.49
Interaction	4	2.275	<1	2.49
Error (within cells)	90	3.234		
Totals	99			

When the mean scores were subjected to treatment by the analysis of variance technique (Table 14), it was found that:

1. there was no significant difference between the mean scores earned by the pupils receiving different treatments;
2. there was no significant difference between the mean scores earned by the pupils in different grades;
3. there were no significant grade level-treatment interactions.

Part Three: Classification of Described Phenomena

Part three of the final test consisted of describing six common phenomena, one at a time, to individual subjects. The subject was asked to: (1) classify each phenomenon as an example of a physical change or a chemical change and (2) verbally explain the basis for his classification. He was also permitted to question the examiner regarding the nature of the change during the testing period. Analysis of the verbal responses will be deferred to a later section of this chapter.

Table 15: Mean Scores Earned on Classification of Described Phenomena, Arranged by Grade Level and Treatment [Maximum possible mean = 6]

Treatment	Grade Level				
	2	3	4	5	6
1	3.400	3.000	3.500	3.600	3.800
2	2.900	3.000	3.300	3.600	4.000

The mean scores earned by the subjects in classifying the described phenomena as examples of physical or chemical changes (Table 15) ranged from 2.90 out of six for the G2-T2 group to 4.00 out of six for the G6-T2 group with the mean scores in both treatment groups of the Grade 3 and 5 populations being identical. At Grades 2 and 4 the groups receiving T1 earned higher mean scores than those receiving T2.

Subjecting these mean scores to treatment with the analysis of variance technique (Table 16) revealed that:

1. there was no significant difference between the mean scores earned by the pupils receiving different treatments;
2. there was no significant difference between the mean scores earned by the pupils in different grades;
3. there were no significant grade level-treatment interactions.

Table 16: Summary Table for Analysis of Variance; Classification of Described Phenomena [α = .05, one-tailed]

Source	df	MS	F	F (Critical)
Method of instruction	1	.250	<1	3.96
Grade level	4	2.560	2.13	2.49
Interaction	4	.350	<1	2.49
Error (within cells)	90	1.203		
Totals	99			

ANALYSIS OF CLASSIFICATION OF PHENOMENA

The test scores earned by the individual subjects on the classification of demonstrated phenomena (Part Two) and on the classification of described phenomena (Part Three) were combined to give the subject a total classificational test score. These data were used to determine which of the groups in Grades 2–6 met the criterion of 50% or more of the subjects earning a score of 65% or higher on the classification of natural phenomena as examples of physical or chemical changes.

Table 17: Number of Subjects Who Correctly Classified 65% or More of the 20 Test Phenomena, According to Grade Level and Treatment [Maximum of 10 subjects per cell]

Treatment	Grade Level				
	2	3	4	5	6
1	4	4	6	5	5
2	2	2	5	3	5

It is noted from Table 17 that 50% or more of the subjects in the T1 groups of the Grade 4, 5, and 6 populations and the T2 groups in Grades 4 and 6 populations achieved a level of success of 65% or higher in correctly classifying the phenomena as examples of physical or chemical changes. The five groups in the T1 population achieved a level of success greater than or equal to the corresponding T2 groups.

ANALYSIS OF VERBAL RESPONSES

The verbal responses given by each subject in support of his classification of the individual phenomena were categorized on the basis of whether or not he referred to the criterion of new material or no new material formation (sometimes inadequate or incorrect). On this basis each subject received a verbal test score with a maximum attainable score of 20.

Table 18. Mean Scores for Verbal Responses Referring to Nature of the Material As the Criterion for Classification of Phenomena, Arranged According to Treatment and Grade Level [Maximum possible mean = 20]

Treatment	Grade Level 2	3	4	5	6
1	6.900	9.100	13.100	15.600	14.800
2	11.700	9.800	14.200	13.000	16.000

It is noted from Table 18 that the mean scores for the use of the nature of the material after the change as the criterion for classifying the test phenomena ranged from 6.90 out of 20 for the G2-T1 group to 15.60 out of 20 for the G5-T1 group. In Grades 4, 5, and 6 subjects in both treatment groups averaged better than 50% in use of the above criterion for classification. Subjects receiving T2 used the criterion more frequently than the corresponding T1 subjects at all but the Grade 5 level.

When these means were subjected to treatment with the analysis of variance technique (Table 19), it was found that:

1. there was no significant difference between the mean scores earned by the pupils receiving different treatments;
2. there was a significant difference between the mean scores earned by the pupils in different grades;
3. there were no significant grade level-treatment interactions.

Table 19: Summary Table for the Analysis of Variance. Support of Classification With Reference to the Criterion of Whether or Not a New Material Was Formed [α = .05, one-tailed]

Source	df	MS	F	F (Critical)
Methods of instruction	1	27.040	<1	3.96
Grade level	4	162.415	4.86	2.49
Interaction	4	34.415	1.03	2.49
Error (within cells)	90	33.311		
Totals	99			

The Newman-Keuls procedure for post hoc comparison of means was applied to the grade level population means. Table 20 reveals that subjects in Grades 4, 5, and 6 referred to the nature of the material as their criterion for classifying the phenomena on a significantly greater number of the items than subjects in Grades 2 and 3.

Table 20: Tests on Differences Between All Pairs of Grade Level Means for References to Nature of Material (Newman-Keuls Procedure)

Grade Level		2	3	4	5	6
	Means	9.30	9.45	13.65	14.30	15.40
2	9.30	-	.15	4.35*	5.00*	6.10*
3	9.45		-	4.20*	4.85*	5.95*
4	13.65			-	.65	1.75
5	14.30				-	1.10
6	15.40					-
			r = 2	3	4	5
$q_{.95}(r, 90)$			2.82	3.38	3.72	3.95
$q_{.95}(r, 90)\sqrt{MS_{error}/n}$ **			3.64	4.35	4.80	5.10

*(p < .05)

**Critical values.

ANALYSIS OF CORRECT CLASSIFICATION WITH CORRECT CONCEPT

Each subject was assigned a test score based on the number of items for which he both correctly classified the item and supported his correct classification with a correct concept of physical or chemical change. Tabulation of these data was utilized to determine which of the groups in Grades 2–6 met the criterion of 50% or more of the subjects earning a score of 40% or higher in supporting their correct classification of natural phenomena as examples of physical or chemical changes with correct concepts of physical or chemical changes.

Table 21: Mean Test Scores for Correct Classifications Supported by Correct Reasons, According to Treatment and Grade Level [Maximum possible mean = 20]

Treatment	Grade Level 2	3	4	5	6
1	2.900	1.800	5.900	5.500	8.100
2	3.700	4.200	5.400	6.900	8.300

Table 21 reveals that the mean scores for the subjects on supporting correct classifications of phenomena with correct concepts ranged from 1.800 out of 20 for the G3-T1 group to 8.300 out of 20 for the G6-T2 group with the T2 groups achieving a higher level of success than their corresponding T1 groups at all but the Grade 4 level. All ten groups achieved a level of success less than 50% of the maximum possible.

Table 22: Summary Table for the Analysis of Variance. Support of Correct Classifications with Correct Concepts [$\alpha = .05$, one-tailed]

Source	df	MS	F	F (Critical)
Methods of instruction	1	18.490	1.58	3.96
Grade level	4	93.140	7.94	2.49
Interaction	4	6.190	<1	2.49
Error (within cells)	90	11.732		
Totals	99			

Subjecting these means to treatment with the analysis of variance technique (Table 22) revealed that:

1. there was no significant difference between the mean scores earned by the pupils receiving different treatments;
2. there was a significant difference be-

Table 23: Tests on Differences Between All Pairs of Grade Level Means for Correct Classification with Correct Concept (Newman-Keuls Procedure)

Grade Levels	Means	3 (3.00)	2 (3.30)	4 (5.65)	5 (6.20)	6 (8.20)
3	3.00	-	.30	2.65*	3.20*	5.20*
2	3.30		-	2.35*	2.90*	4.90*
4	5.65			-	.55	2.55
5	6.20				-	2.00
6	8.20					-
			r = 2	3	4	5
$q_{.95}(r, 90)$			2.82	3.38	3.72	3.95
$q_{.95}(r, 90)\sqrt{MS_{error}/n}$ **			2.16	2.59	2.85	3.02

*($p < .05$)

**Critical values.

tween the mean scores earned by the pupils in different grades;

3. there were no significant grade level-treatment interactions.

It is noted from Table 23 that, when the grade level population means were compared by use of the Newman-Keuls procedure, subjects in Grades 4, 5, and 6 achieved a significantly higher level of success than subjects in Grades 2 and 3 when the criteria for establishing a test score were both a correct classification of a phenomenon and supporting the classification with a correct concept of physical or chemical change.

Table 24: Number of Subjects Supporting Correct Classifications with Correct Reasons, n $\geq$ 40% of the Phenomena, According to Grade Level and Treatment [Maximum cell frequency = 10]

Treatment	Grade Level				
	2	3	4	5	6
1	1	0	3	4	6
2	1	2	3	4	8

It is noted from Table 24 that more than 50% of the Grade 6 population in both treatment groups achieved a 40% or higher level of success in supporting their correct classifications of phenomena with correct concepts of physical or chemical change with the greater number of subjects attaining this level in the T2 group. In Grade 6 70% of the subjects attained the 40% level or higher with fewer than 50% of the subjects in all other grades attaining this level of success.

UTILIZATION OF QUESTIONS BY SUBJECTS

Prior to classifying a phenomenon as an example of a physical or a chemical change, the subject was given an opportunity to ask questions that might assist him in determining the nature of the change. There were 46 out of the 100 subjects (Table 25) who utilized the opportunity to ask questions about the nature of the change prior to classifying it, with a range of from 2 of the 10 in both of the Grade 2 treatment groups to 7 of the 10 in the G5-T1 group. The opportunity to ask questions was utilized by 50% or more of the subjects in both treatment groups of the Grade 3 and Grade 5 populations, the G4-T1 group, and the G6-T2 group.

Table 25: Number of Subjects Utilizing the Opportunity to Ask Questions About the Nature of a Change Prior to Classifying it as an Example of a Physical or a Chemical Change, According to Grade Level and Treatment [Maximum cell frequency = 10]

Treatment	Grade Level				
	2	3	4	5	6
1	2	6	5	7	3
2	2	5	4	6	6

The frequency of use of questions by these 46 subjects ranged from one to 10 out of a possible 20 opportunities with a mean score of 2.72. Of the four subjects who asked whether or not a new material had been formed as a result of the change, three asked only once and the fourth asked 10 times; two of those subjects asking the question only once were in the G6-T1 group and the remaining two were in the G4-T1 group.

CORRELATIONS

The test scores earned by the individual subjects on (1) correct classification of phenomena, (2) reference to the nature of the material as the criterion for classification, and (3) supporting correct classifications with correct concepts were correlated with each other and with selected standard achievement scores within each of the ten groups. Correlation coefficients significantly greater than zero were identified.

From Table 26, it is noted that in no experimental group was there any significant relationship between the abilities of the subjects to classify the test phenomena correctly and their reference to the nature of the material as the criterion for classifying the phenomena. Four of the five groups wherein a significant relationship existed between the ability to classify phenomena correctly and the ability to support correct classifications with correct concepts had received the second method of instruction. Significant relationships between the ability to classify phenomena correctly and standard levels of achievement existed within groups G4-T1 and G5-T2.

Table 26: Correlation Matrix. Correlations of the ability to correctly classify phenomena with: (1) reference to nature of material as the criterion for classification, (2) correct classification with correct concept and (3) selected standard levels of achievement, arranged according to group

Group	Reference to material	Correct classification with correct concept	Science Social Studies	Science	Arithmetic Concepts	Arithmetic Application	IQ
G2-T1	-.5470	-.2016	.3613		-.3814		-.5635
G2-T2	.3075	.8236*	.0769		.4749		.4847
G3-T1	.1886	.5459	.1642		-.4645		.0246
G3-T2	-.0621	.0445	-.3745		-.2791		-.4623
G4-T1	-.4834	.2845		.6999*	.7295*	.5532	.3521
G4-T2	.1268	.6339*		.4153	-.0911	-.2620	.0642
G5-T1	.4436	.6609*		.1207	.1824	-.1023	-.0603
G5-T2	.5410	.7383*		.4539	.6648*	.7193*	.8331*
G6-T1	.4256	.5531		.5678	.3059	.2373	.3126
G6-T2	.3937	.8436*		.4908	.4290	.5154	.1144

*Significant at $\alpha = .05$.

Table 27: Correlation Matrix. Correlations between the frequency of use of the nature of material as the criterion for classification of phenomena and (1) correct classification with correct concept and (2) selected standard levels of achievement, arranged according to group

Group	Correct classification with correct concept	Science Social Studies	Science	Arithmetic Concepts	Arithmetic Application	IQ
G2-T1	.8627*	.0465		.0655		.6841*
G2-T2	.5592	.4968		.6786*		.8586*
G3-T1	.2691	-.1503		-.1803		-.4967
G3-T2	.9123*	.3078		.7681*		.8258*
G4-T1	.0886		-.6212	-.3311	-.5755	-.5366
G4-T2	-.0060		.2653	-.0567	.3205	.4255
G5-T1	.3803		.3784	.5074	.4376	.3492
G5-T2	.8939*		.8240*	.6872*	.8316*	.6014
G6-T1	.2349		.0845	-.1149	-.1466	-.2044
G6-T2	.4214		.6199	.4507	.3266	.2554

*Significant at $\alpha = .05$.

Table 27 reveals that a significant relationship exists between the use of the nature of the material as the criterion for classification and IQ in three of the four groups in Grades 2 and 3 with both Treatment 2 groups showing a significant relationship between the two factors. Only 3 of the 10 groups (G2-T1, G3-T2, G5-T2) exhibited a significant relationship between the use of the nature of the material as the criterion for classification and the ability to support correct classifications with correct concepts. The three groups (G2-T2, G3-T2, G5-T2) where a significant relationship existed between the criterion of nature of material and arithmetic concepts had all received Treatment 2.

It is noted from Table 28 that the three groups (G2-T2, G3-T2, G5-T2) where a significant relationship existed between classifying correctly with correct concepts and IQ and the two groups where significance existed between classifying correctly with correct concepts and arithmetic concepts had all re-

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Table 28:. Correlation Matrix. Correlations between the ability to support correct classifications with correct concepts and selected standard levels of achievement, arranged according to group

Group	Science Social Studies	Science	Arithmetic Concepts	Arithmetic Application	IQ
G2-T1	.1599		-.0407		.4547
G2-T2	.0685		.4139		.6398*
G3-T1	.2922		-.4751		-.0123
G3-T2	.3425		.7637*		.7674*
G4-T1		-.0993	.3038	.3739	.0715
G4-T2		.1216	.0379	-.3100	.2993
G5-T1		.0268	-.0767	-.3262	-.3067
G5-T2		.7467*	.8784*	.8683*	.7303*
G6-T1		.6312	.2824	.2083	.2749
G6-T2		.4380	.3473	.5274	-.0216

*Significant at $\alpha = .05$.

ceived Treatment 2. For the G5-T2 group there was a significant relationship between the ability to classify correctly with correct concepts and each of the four selected standard levels of achievement.

ITEM ANALYSIS

The number of subjects who had correctly classified each test item was tabled according to the grade level of enrollment and treatment.

Demonstrated Phenomena (Table 29)

1. Demonstration No. 4 (Mixing black ink and water) was correctly classified by only 27% of the population; however, it was classified correctly by 50% of the subjects in the G5-T1 group.
2. Demonstration No. 5 (Mixing silver nitrate and sodium chloride) was classified correctly by 79% of the total population with a higher percent of the T2 subjects classifying it correctly. Sixty percent or more of the subjects in each of the ten groups classified it correctly.
3. Demonstration No. 7 (Heating sugar until it turned brownish-black) was correctly classified by 81% of the total population with a higher percent of the T2 subjects classifying it correctly. Eighty percent or more of the subjects in all but the G3-T1 group (40% of the subjects) correctly classified it.
4. The number of subjects who correctly classified the remaining 11 demonstrations ranged from 44% on Demonstration No. 8 to 68% on Demonstration No. 11.
5. Subjects receiving T1 correctly classified 8 of the 14 demonstrations a higher percent of the time than corresponding subjects receiving T2.
6. The only two demonstrations correctly classified by 50% or more of the subjects in each of the ten groups were No. 5 (Mixing silver nitrate and sodium chloride) and No. 13 (Mixing solutions of ammonium hydroxide and copper sulfate).

Grade 2. In Grade 2, 11 of the 14 demonstrations were correctly classified by 50% or more of the subjects in both treatment groups with 8 of these 11 demonstrations being identical for both groups.

Grade 3. There were 11 of the 14 demonstrations correctly classified by 50% or more of the T1 subjects and 10 of the 14 demonstrations correctly classified by 50% or more of the T2 subjects; eight demonstrations were identical for both groups.

Grade 4. In Grade 4, 11 of the 14 demonstrations were correctly classified by 50% or more of the T1 subjects whereas 50% or more of the T2 subjects correctly classified 10 of the demonstrations; eight demonstrations were identical for both groups.

Table 29: Number of Subjects Correctly Classifying the 14 Demonstrated Phenomena, According to Treatment and Grade Level [Maximum cell frequency = 10]

Grade Level	Demonstration 1 T1	1 T2	2 T1	2 T2	3 T1	3 T2	4 T1	4 T2	5 T1	5 T2	6 T1	6 T2	7 T1	7 T2
2	5	5	5	5	7	4	1	3	7	7	8	5	9	8
3	6	9	5	5	5	6	3	2	6	8	3	5	4	8
4	4	8	7	6	8	6	2	2	9	10	7	6	8	8
5	6	8	5	3	6	7	5	2	6	10	6	7	8	9
6	9	7	4	1	8	8	3	4	9	7	9	7	9	10
Totals	30	37	26	20	34	31	14	13	37	42	33	30	38	43
	67		46		65		27		79		63		81	

Grade Level	Demonstration 8 T1	8 T2	9 T1	9 T2	10 T1	10 T2	11 T1	11 T2	12 T1	12 T2	13 T1	13 T2	14 T1	14 T2
2	5	6	4	5	7	7	6	8	7	4	7	5	3	5
3	5	3	6	7	5	4	5	5	7	2	6	8	5	8
4	6	4	2	6	8	7	9	4	6	4	9	9	7	7
5	4	2	7	5	7	6	8	6	6	5	7	6	6	5
6	6	3	3	2	9	7	8	9	7	6	5	8	2	5
Totals	26	18	22	25	36	31	36	32	33	21	34	36	23	30
	44		49		67		68		54		70		53	

Grade 5. For 11 of the 14 demonstrations, 50% or more of the subjects in both treatment groups correctly classified them. There were 13 of the 14 demonstrations correctly classified by 50% or more of the T1 subjects.

Grade 6. Fifty percent or more of the subjects in both of the Grade 6 treatment groups correctly classified 10 of the 14 demonstrations with nine demonstrations being the same for both groups.

Table 30: Number of Demonstrations for Which the Grade Level Populations Ranked First in Terms of Successful Classification of the Phenomena [14 demonstrations]

	Grade Level 2	3	4	5	6
Number of demonstrations	1	1	4	1	8

For each of the 14 demonstrated phenomena the grade level populations were ranked in terms of the number of subjects who had successfully classified the demonstrations. It is noted from Table 30 that the Grade 4 and Grade 6 populations ranked first, on the basis of successful classification of the individual phenomena, on more than 1 of the 14 demonstrations with the frequency of occurrence for Grade 6 population being twice that of the Grade 4 population, 8 to 4.

Described Phenomena (Table 31)

1. The number of subjects who correctly classified the six items ranged from 39% on Phenomenon No. 1 (Building a house) to 70% on Phenomenon No. 5 (Growing of Plants) with more than 50% of the subjects correctly classifying three of the phenomena.
2. Three of the six phenomena were correctly classified a higher percentage of the time by the T2 subjects whereas the remaining three phenomena were correctly classified a higher percentage of the time by the T1 subjects.
3. The only phenomenon correctly classified by 50% or more of the subjects in each of the 10 groups was No. 5 (Growing of plants).

Table 31: Number of Subjects Correctly Classifying the Six Described Phenomena, According to Treatment and Grade Level [Maximum cell frequency = 10]

Grade Level	Described Phenomenon 1		2		3		4		5		6	
	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
2	5	5	6	4	3	4	6	6	8	7	4	2
3	4	3	6	7	5	5	4	7	6	5	5	3
4	3	0	6	7	6	5	6	9	8	8	6	4
5	4	7	8	10	4	3	4	6	8	8	8	2
6	2	6	7	7	7	6	9	7	6	6	7	8
Totals	18	21	33	35	25	23	29	35	36	34	30	19
	39		68		48		64		70		49	

Grade 2. In Grade 2, 50% or more of the subjects in both treatment groups correctly classified three of the six phenomena; in addition, more than 50% of T1 subjects correctly classified a fourth phenomenon.

Grade 3. There were four of the six phenomena that were correctly classified by 50% or more of the Grade 3 subjects in both treatment groups; however, only three of these four were the same for both groups.

Grade 4. Of the six phenomena, four were correctly classified by 50% or more of the Grade 4 subjects in both treatment groups with this percentage of subjects in the T1 group correctly classifying a fifth phenomenon.

Grade 5. In Grade 5, 50% or more of the T1 subjects correctly classified three of the six phenomena and 50% or more of the T2 subjects correctly classified four of the six phenomena. Two of the phenomena correctly classified by 50% or more of the subjects were the same for both treatment groups.

Grade 6. There were 50% or more of the G6-T2 subjects who correctly classified all six phenomena whereas this number of G6-T1 subjects classified five of the six phenomena.

For each of the six described phenomena the grade level populations were ranked in terms of the number of subjects who had correctly classified the phenomena. The Grade 5 and 6 populations attained Rank No. 1 on more than one of the six described phenomena with the Grade 6 population attaining this rank for four of the six phenomena (Table 32).

Table 32: Number of Described Phenomena for Which the Grade Level Populations ranked First in Terms of Successful Classification of the Phenomena [6 described phenomena]

	Grade Level 2	3	4	5	6
Number of demonstrations	0	0	1	3	4

V
CONCLUSIONS AND IMPLICATIONS

CONCLUSIONS

All conclusions in this study are restricted to the procedures utilized, the selected concepts of physical and chemical change, and the population from which the samples were drawn.

1. The procedure in which the teacher formulates and states the generalization to be learned is not superior to the procedure in which the pupil individually formulates the generalization studied.

2. The understanding of the concepts of physical and chemical change achieved by pupils in Grade 6 is significantly higher than that achieved by pupils in Grades 2 and 3 when the criterion is the ability to verbalize the concepts.

3. Children in Grades 2–6 do not differ significantly in their understanding of the concepts of physical and chemical change when the criterion is the ability to correctly classify natural phenomena as examples of physical or chemical changes.

4. The understanding of the concepts of physical and chemical change achieved by children in Grades 4, 5, and 6 is significantly higher than that achieved by children in Grades 2 and 3 when the criterion is the ability to support correct classifications of natural phenomena as examples of physical or chemical changes with correct reasons.

5. Children in Grades 2–6 do not utilize the opportunity to ask questions to confirm the conclusion they draw regarding the classification of a specific change in matter.

6. The classificational concepts of physical and chemical change cannot be taught in Grades 2 and 3 and can be taught only in selected instances in Grades 4 and 5.

7. The classificational concepts of physical and chemical change can be successfully taught in Grade 6.

8. There is no significant relationship between the number of times pupils in Grades 2–6 correctly classify natural phenomena as examples of physical and chemical change and the number of times they refer to the nature of the material (sometimes inadequate or incorrect) as their criterion for classification.

9. There is a significant relationship between the scores earned by pupils in Grades 2–6 who received Treatment No. 2 (Teacher formulated and stated the generalization.) on the classification phase of the test and the number of times they supported correct classifications with correct reasons.

10. The number of times pupils in Grades 2–6 correctly classify natural phenomena as examples of physical or chemical changes is not significantly correlated with IQ or past achievement in science and mathematics.

11. The number of times pupils in Grades 2 and 3 who receive Treatment No. 2 (Teacher formulated and stated the generalization.) refer to the nature of the material (sometimes inadequate or incorrect) as the criterion for classifying changes in matter as physical or chemical is significantly correlated with IQ and past achievement in arithmetic.

12. The discovery approach does not appear to be superior to a deductive approach in teaching the classificational concepts of physical and chemical change.

IMPLICATIONS

The classificational concepts of physical and chemical change probably should not be included in the elementary school curriculum below Grade 6 if the criterion for success is the attainment of higher levels of understanding of the concepts. In addition, it cannot be assumed that the concepts of physical and chemical change, identified as being classificational in scope, can be included in the elementary school curriculum at the lower grade levels even when the instructional sequence provides first-hand experiences for formulating the concepts.

The nature of the physical stimuli employed in the instructional sequence utilized in the teaching of the classificational concepts of physical and chemical change does not seem to be a critical factor except for those phenomena which involve a color change—pupils in Grades 2–6 apparently assume that a change in color during a change in matter is a reliable indicator that the change was chemical.

It appears that there should be a concern for the development of evaluation instruments which allow a child to demonstrate his knowledge of a concept, rather than relying solely on the ability of the child to verbalize his conceptual understanding.

There is an apparent need for additional and continuous research pertaining to the grade-placement of selected science concepts and regarding the preparation of instructional sequences by which these concepts can be efficiently taught; the determination of the location of concepts within the curriculum and the selection of the pedagogical techniques to be utilized in teaching them must be based on the collection of hard data.

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