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THE USE OF STATIC AND DYNAMIC MECHANICAL MODELS IN TEACHING ASPECTS OF THE THEORETICAL CONCEPT, THE PARTICLE NATURE OF MATTER.

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THE RELATIVE EFFECTIVENESS OF TWO TYPES OF MECHANICAL MODELS FOR TEACHING ELEMENTARY SCHOOL STUDENTS TO USE THE PARTICLE IDEA OF MATTER TO EXPLAIN CERTAIN PHYSICAL PHENOMENA WAS INVESTIGATED. SUBJECTS WERE RANDOMLY SELECTED FROM STUDENTS ENROLLED IN GRADES TWO THROUGH SIX IN A SCHOOL SYSTEM. A SERIES OF DEMONSTRATIONS AND RELATED QUESTIONS WERE USED TO SUBDIVIDE THE POPULATION INTO THOSE WHO DID AND THOSE WHO DID NOT USE THEORETICAL MECHANICAL MODELS IN EXPLAINING PHYSICAL PHENOMENA. STUDENTS WERE THEN RANDOMLY ASSIGNED TO TREATMENT GROUPS. ONE GROUP RECEIVED INSTRUCTION THROUGH USE OF A DYNAMIC MODEL, A SECOND GROUP RECEIVED INSTRUCTION INVOLVING A STATIC MODEL, AND A CONTROL GROUP RECEIVED NO INSTRUCTION. ALL SUBJECTS IN EXPERIMENTAL GROUPS WERE TESTED, INSTRUCTED, AND RETESTED ON AN INDIVIDUAL BASIS. APPLICATION OF ANALYSIS OF VARIANCE TO DATA REVEALED THAT (1) THERE WAS A SIGNIFICANT DIFFERENCE BETWEEN THE SCORES OF STUDENTS IN THE EXPERIMENTAL GROUPS AND THOSE IN THE CONTROL GROUP, (2) SCORES OF STUDENTS IN THE GROUP THAT USED MODELS IN EXPLAINING PHYSICAL PHENOMENA WERE SIGNIFICANTLY HIGHER THAN THOSE OF THE NON-MODEL STUDENTS, AND (3) THERE WERE NO SIGNIFICANT DIFFERENCES IN ACHIEVEMENT BETWEEN GRADE LEVELS. THE DYNAMIC MODEL WAS NOT SUPERIOR TO THE STATIC MODEL IN TEACHING STUDENTS TO USE MODELS IN EXPLAINING PHYSICAL PHENOMENA. (AG)

THE USE OF STATIC AND DYNAMIC MECHANICAL MODELS IN TEACHING ASPECTS OF THE THEORETICAL CONCEPT THE PARTICLE NATURE OF MATTER

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THE USE OF STATIC AND DYNAMIC MECHANICAL MODELS IN TEACHING ASPECTS OF THE THEORETICAL CONCEPT THE PARTICLE NATURE OF MATTER

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PREFACE

The goal of the Center is to contribute to an understanding of, and the improvement of educational practices related to, cognitive learning by children and youth. Of primary concern are the learning of concepts, such as those which comprise the main body of organized knowledge in science or in mathematics, and the nurturing of related cognitive skills, such as those which are involved in problem solving, creative production, or in reading. Three research and development programs—Conditions and Processes of Learning, Processes and Programs of Instruction, and Facilitative Environments—differentiate the types of activities conducted at the Center.

Through the use of mechanical models of two types, a basic concept of science, the particle nature of matter, was effectively taught to children in Grades 2-6. Although a factor of time of acceptance of abstract theoretical ideas appeared to be operating, the effects of IQ, grade level, age, and past achievement in science and mathematics upon learning to use the theoretical model were not significant. The authors conclude that those preparing instructional programs in science for the elementary school "may consider that children in Grades 2-6 can form theoretical concepts if provided with concrete experience analogies as a part of an otherwise appropriate program."

Herbert J. Klausmeier
Co-Director for Research

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ABSTRACT

This study is concerned with determining the relative effectiveness of the use of two kinds of theoretical mechanical models in teaching subjects attending an elementary school to use the particle idea of matter in explaining certain physical phenomena. The clinical method employed in this study was similar to that used by Piaget in his studies of mental development. It consisted of personal individual interview-testing, teaching, and retesting of subjects composing a random sample population drawn from the total population in Grades 2-6 in Janesville, Wisconsin.

The first test was to determine whether all or any subjects within the several grade levels used theoretical mechanical models in explaining physical phenomena and consisted of three demonstrations and appropriate questions. From the testing it was learned that the population in Grades 4, 5, and 6 could be dichotomously divided into those who used models and those who did not; the population in Grades 2 and 3 did not use models in any explanations.

Subjects were randomly assigned within the Modeler and Nonmodeler groups to three treatment groups: Treatment 0—the group that received no instruction by the investigator; Treatment 1—the group that received instruction in which a static model was employed; and Treatment 2—the group that received instruction in which a dynamic model was employed.

The effects of the periods of instruction utilizing no treatment, the static model, and the dynamic model were measured directly; the subjects observed the eight test demonstrations and then gave their explanation of the observed physical phenomena. When analysis of variance techniques were applied to these data from the eight test demonstrations it was found that:

1. The difference in scores between groups receiving Treatment 1 or Treatment 2 and those receiving Treatment 0 was significant and may be attributed to the nature of the treatment received.
2. The scores earned by the Modeler group were significantly higher than those earned by the Nonmodeler group when both received the same treatment.
3. There were no significant differences in achievement between grade levels and no significant interaction effects were found.

To determine whether Treatment 1 or Treatment 2 produced superior results, post hoc comparisons of significance were made using the Scheffe test. The dynamic mechanical model, Treatment 2, though usually numerically superior, was not significantly superior to the static mechanical model, Treatment 1, as an instructional aid in teaching the use of acceptable models, as the particle theory of matter, in explaining physical phenomena to children in Grades 2-6.

I
PROBLEM

INTRODUCTION

Model formation has been one of the important strategies employed by scientists in their quest for an understanding of nature. Such authors as Nagel (1961) and Nash (1963) have repeatedly stated the strategic importance of models in the development of both the physical and biological sciences. These models may be mechanistic or idealistic but must function as analogies to the hypothetical or real world. The role of models in the process of learning is receiving increasing attention as evidenced by Bruner (1966) and the Commission on Science Education of the American Association for the Advancement of Science (1964).

For the purpose of this investigation a model is defined as a mechanistic representation of a hypothetical or a real part of nature. A model might also be thought of as an analogy.

The strategic place of models in the development of such concepts as the particle nature of matter and the hypothesized importance of models in the learning process form the basis of the present investigation.

THE PROBLEM

To determine the relative effectiveness of the use of static and dynamic mechanical models in teaching elementary school children the theoretical concept the particle nature of matter.

Prerequisite to this is the determination of whether subjects of elementary school age use acceptable models in explaining their observations of selected physical changes.

Several sub-problems will also be investigated.

A. Do subjects in Grades 2-6 who do not use acceptable nonanimistic nonmagical models change their methods of explaining physical phenomena when no appropriate instruction is given?

B. Do subjects in Grades 4, 5, and 6 who use acceptable models in explaining physical phenomena continue to use acceptable models when no appropriate instruction is provided?

C. Do subjects in Grades 2-6 who do not use nonanimistic nonmagical models in explaining physical phenomena learn to use appropriate models when provided with a period of appropriate instruction?

D. Do subjects in Grades 4, 5, and 6 who use nonanimistic nonmagical models in explaining physical phenomena improve in this ability when provided with a period of appropriate instruction?

E. How do the model usage test scores of subjects who already use nonanimistic nonmagical models in explaining physical phenomena compare with the scores of the subjects who do not use nonanimistic nonmagical models in explaining physical phenomena when both are provided with the same instruction?

F. Is the grade level of enrollment of the subject in school a factor in determining his level of achievement in the use of nonanimistic nonmagical models in explaining physical phenomena?

G. What is the degree of correlation between the model usage test score and grade level of enrollment, age, IQ, mathematics achievement level, and science achievement level?

BACKGROUND OF THE PROBLEM

The place of models in the progress of science as well as in the teaching of science is generally accepted by scientists and teachers of science. The use of analogies or models as a basis for new hypotheses and theories is discussed by scientists from several points of view. Wilson (1952) describes the use of models as a means of making hypotheses understandable or acceptable to the human mind.

> The human mind being what it is, it is understandable that hypotheses are usually constructed on the basis of analogies with other known phenomena. . . . The desire to describe phenomena in terms of familiar concepts has led to the widespread use of mechanical models, especially in physics. . . . Most people find concrete models the easiest way to see additional implications for a theory. New experiments are thereby suggested.

Nash (1963) describes the use of models in science as a means of idealizing phenomena when such phenomena include uncontrollable factors. Models are a means of simplification for better comprehension.

> We think of science as based on our experience of the world, and so it is. Yet sometimes we seem to ignore that experience, even to deny it. Rather than pondering our real experience of real lever systems we set ourselves to contemplate fictions—an ideal lever and the ideal law thereof. In so doing we make an immense gain. The raw phenomena are complicated and variable; the ideal law, which only sketches them, offers an ideally simple statement about "ideal" phenomena. . . . We begin the difficult task of theoretic construction with ideally simple entities and relations—with readily manipulable fictions represented in terse, abstract, often symbolic form. Such entities are the partless points and widthless lines of geometry, the mass-points (and ideal lever) of mechanics, the ideal gas of pneumatics, the ideal solutions of chemistry—all of them represented by ideal laws. Setting out from these, we may be able to arrive at a conception of some very general postulates from which "follow" a multitude of colligative relations (laws).

Implications of Theoretical Concepts of Science

Theoretical concepts are the inventions of men's minds and are the guidelines by which science moves ahead.

> Science is concerned with finding out how the world ticks through the interactions of observations, ideas, and controlled experiments unified by concepts or conceptual schemes. Science is concerned with ideas, not things, although the ideas often are ideas about things. The ideas are created in men's minds. (Roller, 1960)

The development of models is an integral part of the history of the development of new theories in science.

> Most theories, at any rate, are generated within the matrix of some model and are codified, with at best only casual mention of any rules of correspondence, in terms of an interpretation for their fundamental premises. . . . Enough has perhaps been said to make clear what is to be understood by a model (or interpretation) for a theory. However, there has been only negligible discussion of the rationale for having models, or of the role played by models in the construction of theories and in the expansion of their range of application. . . . The suggestion was briefly made that explanations can be regarded as attempts at understanding the unfamiliar in terms of the familiar, insofar as the construction and development of explanatory systems are controlled, as they frequently are, by a desire to find and exploit structural analogies between the subject matter under inquiry and already familiar materials. . . . In any event, the history of theoretical science supplies plentiful examples of the influence of analogies upon the formation of theoretical ideas; and a number of outstanding scientists have been quite explicit about the important role models play in the construction of new theories. . . . Perhaps no scientist of first rank has been so clearly aware as was Maxwell of the place of analogies in the conduct of physical research and in the formulation of theories. (Nagel, 1961)

> . . . to grasp such physical ideas, we always seek models or analogies. . . . The analogy invests the formalism with experimental relevance, and so makes of it a scientific theory; the analogy allows us to hold the physical ideas in mind, and so makes it possible for us to use that theory. . . . There is then overwhelming evidence for the conclusion Schrödinger puts shortly: "Most physicists, whether or not they confess to it, are using some kind of model-picture." . . . Surely one can generalize to all fields of science the conclusion Born puts thus: "All great discoveries in experimental physics have been due to the intuition of men who made free use of models, which were for them not products of the imagination, but representative of real things." (Nash, 1963)

Implications of Teaching Concepts in Science

The growing emphasis on science within our culture necessitates a careful look into the type of science being taught in the elementary schools and also into the methods of teaching that science. With the ever increasing and changing products of science it becomes more necessary to gain some understanding of the nature of the processes by which these products are attained and altered.

The importance and function attributed to models in one of the recent curriculum reforms, Science—A Process Approach, is stressed by the Commission on Science Education of the American Association for the Advancement of Science (1964).

> The basic ingredient of a good model is ideas which explain observations and which lead to correct predictions. . . . we do not ask the child to postulate complex models. Rather, we hope he will be able to present ideas or models about how something works which is within the scope of his experience and knowledge. Here, the child may let his imagination go, but he will have to do so in a logical manner for his model must fit the facts and also fit new observations when they become available. For example, as the child develops a concept or model of the structure of matter, he may first think of matter as being continuous. Later he will find that this model does not explain certain characteristics of matter and he may postulate a model of matter as made of many small particles. Which of these models fits the facts better? Which may be used better to explain new observations he makes about dissolving substances and change of liquids into gases? The process of model formulation should help give the child a real "feel" for the potentialities and satisfactions of the scientific approach.

One of the processes stressed by the Chemical Bond Approach (1964) group for secondary school chemistry is the use of mental models. Part III of the text is entitled "Models as Aids to the Interpretation of Systems." In addition to the use of mental models, the group has also made use of physical models to gain insight into the behavior of metals. The Physical Science Study Committee (1960) course has entitled Chapter 15 "The Particle Model of Light."

Several psychologists have written about the importance of models in the teaching and learning of science. Suchman (1964) has reported from his studies in inquiry training that models are a part of the inquiry cycle.

> Two kinds of scanning are used: scanning the field for data, and scanning the store of ideas for conceptual models. These comprise two parts of the inquiry cycle. A child absorbs a percept and he tries to find a model he can use to assimilate it. Then, providing assimilation is incomplete, he performs some action to generate new data. At the same time that he acquires new data, he scans for new models on which to test the data. He endeavors to match the data coming in with the models being tried out. At some point the match between the data and a model is made.

Bruner (1966) relates model development to mental development.

> I am inclined to think of mental development as involving the construction of a model of the world in the child's head, an internalized set of structures for representing the world around him. These structures are organized in terms of perfectly definite grammars or rules of their own, and in the course of development the structures change and the grammar that governs them also changes in certain systematic ways. The way in which we gain lead time for anticipating what will happen next and what to do about it is to spin our internal models just a bit faster than the world goes.

Implication of the Particle Nature of Matter

One of the theoretical concepts that has been of great value in the understanding of science has been the particle nature of matter. Feynman (1963) emphasized the primacy of this concept.

> If, in some cataclysm, all of scientific knowledge were to be destroyed, and only one sentence passed on to the next generations of creatures, what statement would contain the most information in the fewest words? I believe it is the atomic hypothesis (or the atomic fact, or whatever you wish to call it) that all things are made of atoms—little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another. In that one sentence, you will see,

there is an enormous amount of information about the world, if just a little imagination and thinking are applied.

The National Science Teachers Association (1964) cites the particle nature of matter as one of its important conceptual schemes.

> The unprecedented importance of science requires intensive study of efficient methods for transmitting to our children the principal intellectual achievements of science, together with some understanding of how these achievements were, and are being, obtained.
>
> The first conceptual scheme was: All matter is composed of units called fundamental particles; under certain conditions these particles can be transformed into energy and vice versa.

The importance of the conception of matter being composed of small particles to the development of modern science is stressed by Glasstone (1958).

> From the time of Dalton the atomic hypothesis has played an increasingly important role in science, first in chemistry and later in physics. . . . Today the arguments in favor of the atomic structure of matter are so numerous and convincing that the concept is universally accepted as an established fact rather than a theory.

Theoretical Concept

A theoretical concept is here used as an abstraction developed in the human mind to explain observations of phenomena or predict the outcome of experiments.

> Thus, the most significant activity which is made possible with the use of theory is the interpretation of experience which would not otherwise be interpretable.
>
> Theory, when it is made functional, is cast into some form or model. That is, the postulates which comprise the theory are embedded into a form which can readily be imagined or observed. (Belth, 1965)

Nagel (1961) stated concerning theoretical schemes:

> . . . theoretical as well as experimental considerations have led physicists to ascribe to electrons (and to other entities postulated by quantum theory) apparently incompatible and in any case puzzling characteristics.
>
> Many physicists have therefore concluded that quantum theory cannot be viewed as a statement about an "objectively existing" domain of things and processes, as a map that outlines even approximately the microscopic constitution of matter. On the contrary, the theory must be regarded simply as a conceptual schema or a policy for guiding and coordinating experiments.

Models have occupied an important place in science in the development of theories to explain observable phenomena. As children learn they may use models in the assimilation of new percepts. It therefore seems appropriate and economical to have children <u>learn science</u> with the employment of models for interpretation and explanation of natural phenomena.

II
REVIEW OF RELATED STUDIES

Although no research is known to have been conducted specifically to determine the effectiveness of models in teaching children a theoretical concept such as the particle nature of matter, a considerable amount of research has been conducted concerning children's explanations of natural phenomena.

The work of Jean Piaget has shed much light on the nature of children's explanations of natural phenomena and has provided the impetus for numerous other studies. Piaget's study of children's explanations of natural phenomena has been primarily for the purpose of providing a base from which to develop an understanding of the mental processes of children. Flavell (1963) has defined the aims of Piaget.

> It is possible to give a rough definition of Piaget's principal scientific concerns in a single sentence: he is primarily interested in the theoretical and experimental investigation of the qualitative development of intellectual structures. . . . We need to make clear precisely what Piaget's developmental approach—the study of the genetic dimension--does and does not involve. It does involve the description and theoretical analysis of successive ontogenetic states in a given culture. Thus behavior change from less to more advanced functioning is the primary datum. Further, it involves painstaking comparisons among these successive states; the dominant characteristics of a given state are described in terms of states preceding and states following. It is characteristically not concerned with any systematic exploration of other independent variables which may temporarily accelerate or retard the appearance of the behavior studied.

One of the methods used by Piaget is the verbal interview with the child concerning some concrete event. In most cases a demonstration is performed for the child to observe after which the interview is conducted.

Huang (1930) studied children's explanations of strange phenomena by using the clinical method to elicit explanations of demonstrations that involved illusions, tricks, and direct problems. From the population of 40 children aged 4.8 to 8.11 and 11 college girls, he found that nearly all the explanations were naturalistic physical concepts, some very simple, with few instances of finalistic, magical, moral, animistic, artificialistic, or mystical causality. Huang attributes this difference to Piaget's findings, which included many of the above types of explanations, to a difference in environmental factors of the subjects and in part to the type of question asked. Piaget obtained many of his mystical explanations in regard to questions about the stars, winds, etc.—a type of question that Huang did not use. He reports that when adults did not have prior knowledge their answers were very similar to those of children.

Deutsche (1937) studied the development of children's concepts of causal relations by the use of two types of test situations. The first test included the use of a demonstration after which the children supplied explanations and the second test consisted of a list of questions without any demonstrations. The tests were administered to 732 children in Grades 3-8. Her findings were in contrast to those of Piaget in that she found no evidence that children's reasoning develops by stages since she found but a slight increase in materialistic explanations with age and also found that the classification of causal thinking into 17 types did not appear to be useful.

Another study which received its impetus from Piaget is that of Oakes (1947), a study of children's explanations of natural phenomena. The study was conducted with children from four grade levels, K, 4, 5, and 6, and also a group of nonscience college teachers. Oakes states:

The interest of the present author is not so much that of the psychologist as that of the elementary science teacher in the explanations themselves. An attempt is made to classify the explanations from the latter viewpoint.

Some of the questions were presented as single demonstrations and others were given as purely verbal questions. Oakes' findings are in agreement with Huang and Deutsche. Some of his conclusions were:

1. Each subject, regardless of age, mental ability, or grade level, gave explanations of a wide variety of types. All types of answers were given by all age groups. . . .

4. No evidence was found to corroborate Piaget's interpretation that there is a definite stage in the child's thinking which is characteristic of a given age.

5. Although a few responses were enigmatic, the great majority were matter-of-fact, nonmetaphysical; in other words, naturalistic.

6. In explaining experiments which they had seen, the children gave a higher percentage of cause-and-effect (physical) explanations than they did in response to verbal questions.

7. It appears from the results of the study that children can learn correct explanations of many natural phenomena and most of them are eager to do so.

8. In general, understanding of essential relationships increases with age among children. However, some answers given by individual children in K were superior to those given by older children; a few of those in VI were below the average for K. . . .

10. The nonscience adults in this study followed no definite procedure in explaining phenomena with which they were unfamiliar. Their responses classified as Physical often indicated lack of correct concept; they fumbled for words, made wild guesses, and had little clear understanding of true causal factors.

In 1962, McNeil and Keislar reported a study involving the ability of lower elementary school children to form and use concepts related to molecular theory.

Seventy-two pupils randomly selected from lower elementary classrooms were individually interviewed to determine their conceptualizations of certain natural phenomena. The interview schedule permitted responses to open-ended questions calling for explanations of events corresponding to evaporation and condensation, e.g., clouding mirrors, drying clothes, boiling water, forming dew, falling rain, etc. A trained observer recorded all responses.

Categories of responses in order of recorded frequency were:

1. Mechanistic explanations at concrete and functional levels where the cause and effect relationship was dependent upon direct observation. The explanations were made on the basis of incidental and sometimes irrelevant features or were founded on the manner of use and value.

2. Failure to explain, chiefly, "I don't know."

3. Animistic and religious explanations where phenomena to be explained were ascribed as alive and conscious, or where the explanations were in terms of Deity.

4. Abstract interpretations where explanations were mechanical with the induction of the theoretical principle involved.

Noteworthy in this study also was the infrequency of the use of supernatural and animistic forces accounting for the various phenomena.

For the second part of the study, six children were selected from the first grade to receive individual standardized instruction utilizing 500 picture cards concerning the molecular motion in solids, liquids, and gases and to explain events associated with evaporation and condensation.

When molecules in a liquid are heated, they gain speed by which they overcome their attraction and form gas and when molecules of gas are cooled, they are pulled together, forming droplets of liquid.

Their conclusions were: (1) children tend to develop functional rather than animistic and theoretical approaches to interpretations of natural phenomena; (2) under certain conditions children in the first grade can correctly answer oral questions about molecular theory, responding in theoretical terms for which there is no immediate reality even though questions differ from those asked during instruction.

A study of 3-, 4-, and 5-year-old children was conducted by Wann (1962), supporting the work of Isaacs (1938), which points out that the preschool children

> . . . are highly motivated to explore, to test the accuracy of their observations of the things and events in their environment. Some animism and reliance on magical explanations were evident, but the cases in which children pushed for real explanations far outnumber the cases of animism and magic.

Inbody (1963) examined 50 kindergarten children using the individualized demonstration-interview technique to ascertain their understanding of natural phenomena as presented in elementary science textbooks. The children were presented with 12 experiences, eight involving demonstration of material phenomena, two were presented with pictures, and two were purely verbal. He found the children's explanations could be classified into six general types.

> 1. Explanations which were fairly complete, generally correct, causal in nature, and with a minimum of verbalization.
> 2. Explanations which were plausible, causal in nature, but with incorrect causative factors given.
> 3. Explanations which were generally correct but appeared to be largely verbalistic because of the lack of additional explanation or justification.
> 4. Explanations which were generally incorrect, involving no causation, animistic, or referring to God or Jesus.
> 5. Explanations which were merely descriptions or restatements of observations.
> 6. Responses which provided no explanation.

These six categories when ranked in order of most used categories to least used categories appeared as 2, 4, 1, 5, 3, 6 emphasizing again children's use of causal explanation. Phenomena with which children had direct physical contact, such as freezing and thawing, were most often explained with an awareness of causality.

King (1965) reported a study with 1,235 children ages six to eleven in the development of scientific concepts, utilizing a questionnaire and follow-up of the answers by interview. A schedule of 70 questions arranged into five categories was presented to classes by the teachers in order to insure a normal classroom atmosphere. There was a steady increase in answers for 24 of the questions along with an increase in age. King stated:

> Also, where children had the opportunity to give free answers to the questions on sky and night, types of responses were spread through all the age groups and no one age group had a monopoly on answers of a given type. Scientific explanations, verbal descriptions, religious references, naive conjections could be found at all ages for boys and girls. Experience in and out of school and a vocabulary increasing with age seemed to be the main factors that determined the types of answers given by boys and girls to these two questions. This agrees with the study by Oakes who found no evidence "to corroborate Piaget's interpretation that there is a definite stage in the child's thinking which is characteristic of a given age."

The present study is closest in nature to that of Anderson (1964) as it deals with models used in the explanation of physical phenomena. Most of the studies cited dealt with the classification of explanations whereas in the present study the interest is in whether children do use models in explaining physical phenomena and which of two types of models is more effective in teaching the use of the model the particle nature of matter in explaining physical phenomena.

III
PROCEDURE

This study is concerned with determining the relative effectiveness of the use of two kinds of theoretical mechanical models in teaching subjects attending an elementary school to use the particle idea of matter in explaining certain physical phenomena. Since the procedures for teaching the use of theoretical models are not established and the devices used here are small, it was decided to use the clinical approach in all phases of the study. It was observed that other advantages, as the nature of the explanations subjects gave when they did not give accepted explanations, were enjoyed as a result of this approach.

The clinical method employed in this study was similar to that used by Piaget in his studies of mental development. It consisted of personal individual interview-testing, teaching, and retesting of children composing a random sample population drawn from the total population in Grades 2-6 in Janesville, Wisconsin.

METHOD

Although the clinical method employed here was similar to that employed by Piaget there were some definite differences due to differences in goal. Since Piaget was concerned with learning more about the sequential development of the intellectual structure of children he allowed the child to determine the direction of the interview. Piaget (1960b), "The questions we shall ask them will be determined in matter and form, by the spontaneous questions actually asked by children of the same age or younger."

In this investigation the concern is with the level of development of the subjects and their capacity to learn to use theoretical models in explaining certain physical phenomena, so the investigator structured the procedure. The technique employed here involved the use of demonstrations of physical phenomena selected by the investigator for description and explanation by the subjects. The investigator's questions were designed to ascertain (1) whether the subjects had seen what happened and (2) the nature of the subjects' explanation of their observations. The first question required the subjects to describe what they had observed. The second question was not simply formed as "Why did this happen?" but rather was "What do you think the ball must be like so that this could happen?" The method of phrasing required the subjects to explain their observations in terms of what the material was imagined to be like. The subjects were encouraged to "make up" explanations that seemed reasonable to them. Questions following these two were more flexible and determined primarily by the nature of the responses of the subjects. The intent was to clarify what they had seen and how they had explained their observations. Typical questions were "Can you tell me a bit more about this?" or "Do you think that really helps you explain what you saw happen?"

The sequence followed was that of Test—Teach—Test. The first test was utilized as a means of determining whether all or any subjects within the several grade levels used theoretical mechanical models in explaining physical phenomena. If all subjects at all levels used models the study would be valueless. If none of the subjects used models the study would be simplified. If some did and some did not, a more sophisticated design would be necessary.

The first test included three demonstrations and appropriate questions.

Demonstration 1. Ball and ring. At room temperature the ball fit through the ring. When the ball was heated it no longer would fit through the ring. Observation—the solid ball seemed to be bigger with reference to the ring. Expansion of a solid. (See Figures 1 and 2.)

Demonstration 2. An air filled florence flask was capped with a toy balloon. At

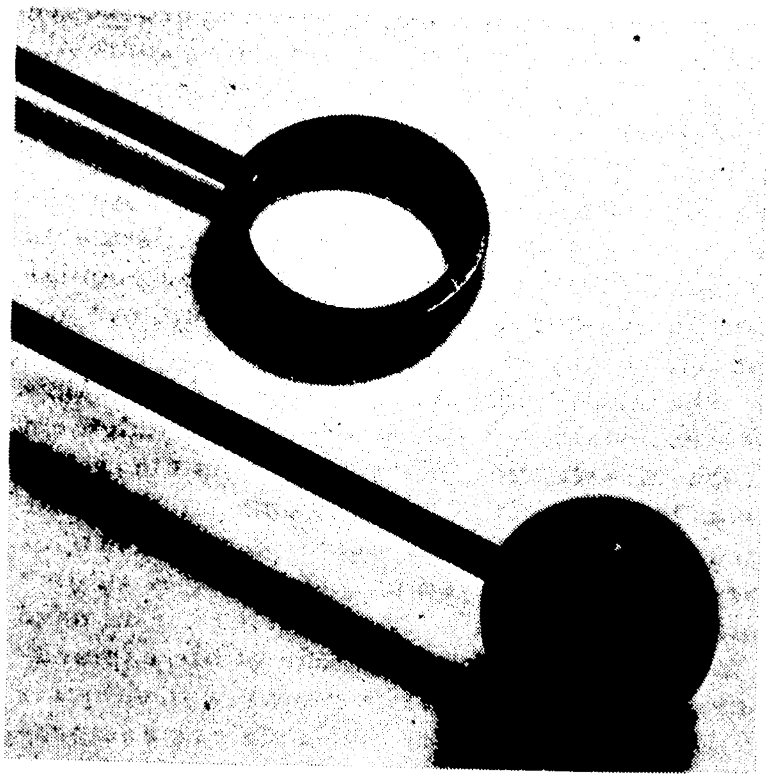

Fig. 1. Ball and ring apparatus at room temperature

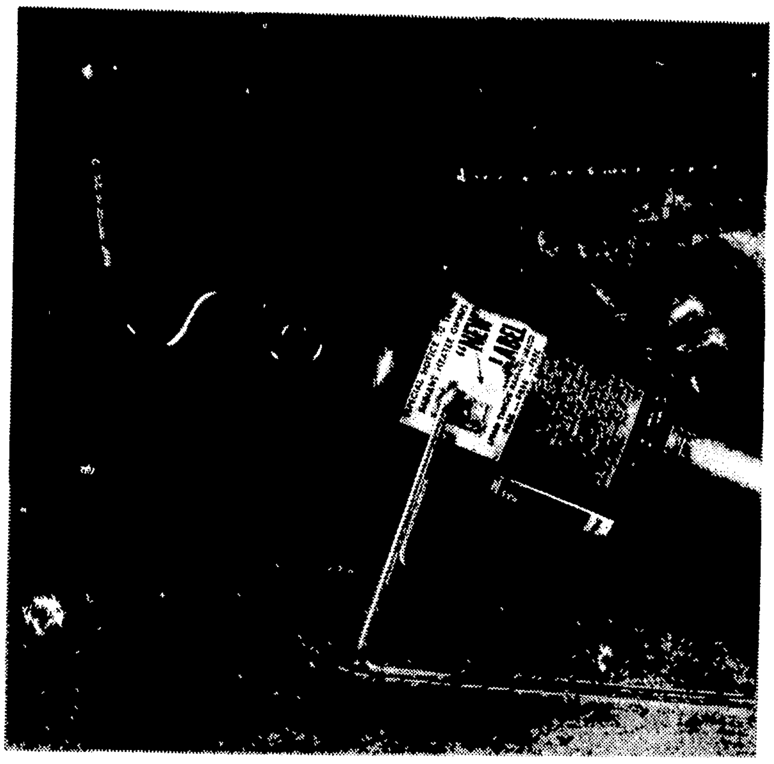

Fig. 2. Ball being heated by a propane burner

room temperature the balloon was not inflated. As the flask was heated, the balloon became inflated. Observation—the balloon was inflated as the flask was heated. Expansion of a gas. (See Figures 3 and 4.)

Demonstration 3. A florence flask filled with water was closed with a one hole stopper containing a six-inch piece of glass tubing. The level of the water in the tube at room temperature was marked. When the flask was heated the water level in the tube went up. Observation—the level of the water in the tube in the flask went up. Expansion of a liquid. (See Figures 5-7.)

Fig. 3. Balloon on flask prior to heating

Fig. 4. Balloon on flask after heating with a burner

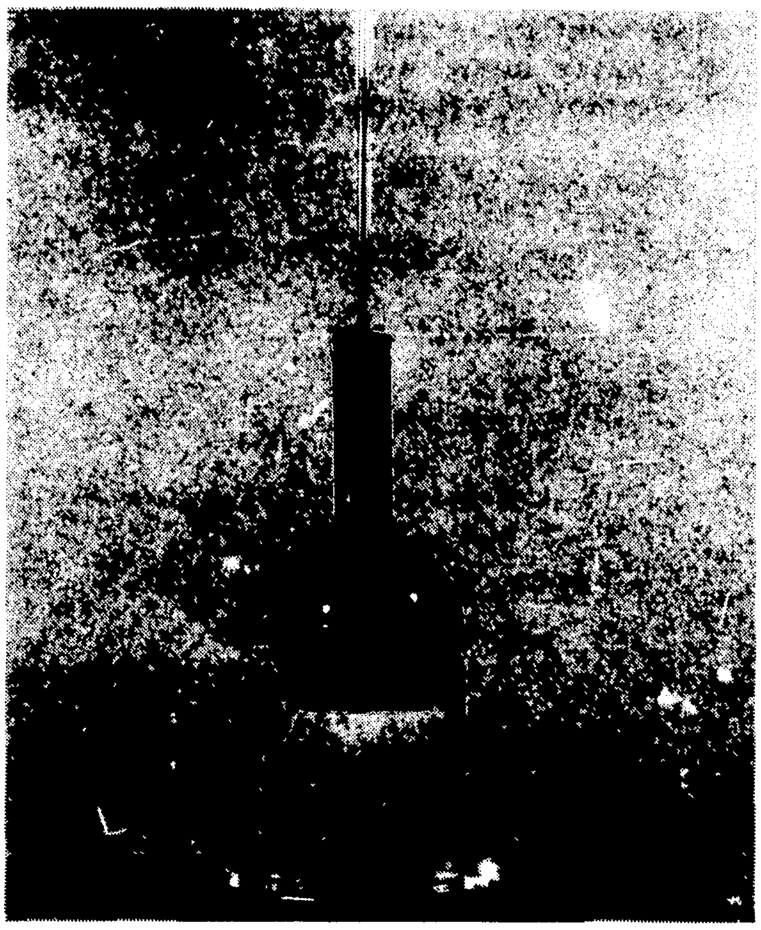

Fig. 5. Florence flask filled with colored water and set in a beaker of heated water

The administration of the testing procedure revealed that some subjects did and some did not use models in explaining certain physical phenomena. It was then known that the population in Grades 4, 5, and 6 could be dichotomously divided into those who used models and those who did not and that a more sophisticated research design was necessary. The population in Grades 2 and 3 generally did not use models in any explanations.

The classification of subjects as Modelers or Nonmodelers was a matter of the judgment of the investigator. A subject was classified as a "Modeler" if he used a nonanimistic nonmagical model in his explanation of two or three of the observed phenomena. A subject was classified as a "Nonmodeler" if he used a model in only one or in none of his explanations. Excerpts from interviews with subjects during the selection of the Modelers are presented in the appendix.

The consistency of the investigator's judgment in the classification of subjects as Modelers or Nonmodelers was checked by submitting tape recordings of ten interviews to a panel of ten professional science educators for classification. Each member of the panel individually classified all of the interviews with an initial agreement of 98 per cent. After a brief

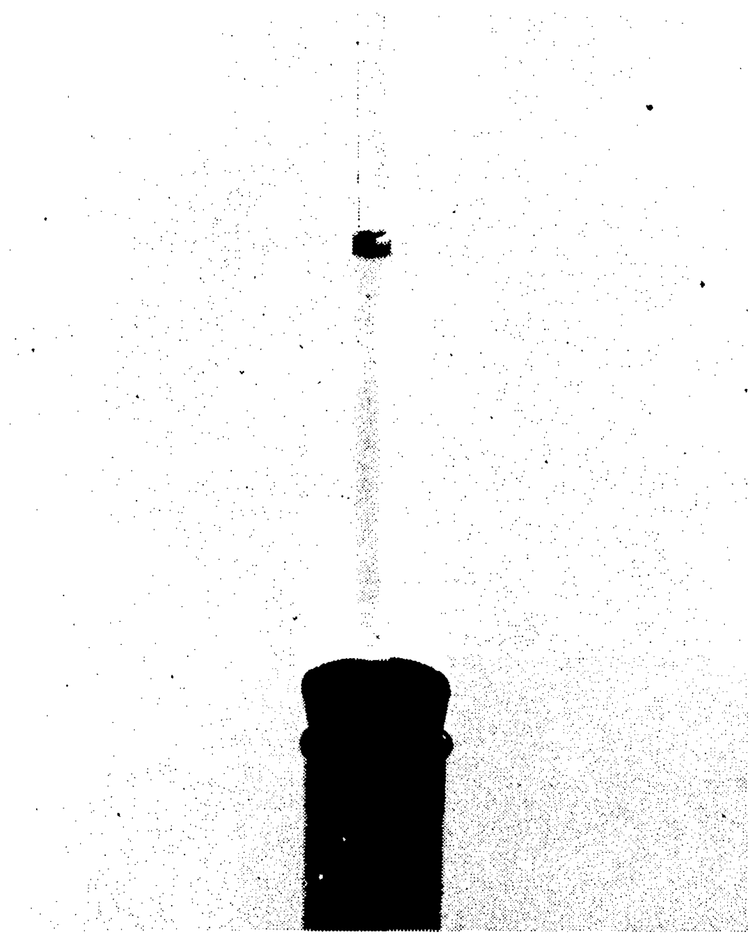

Fig. 6. Water level in tube prior to flask being placed in warm water

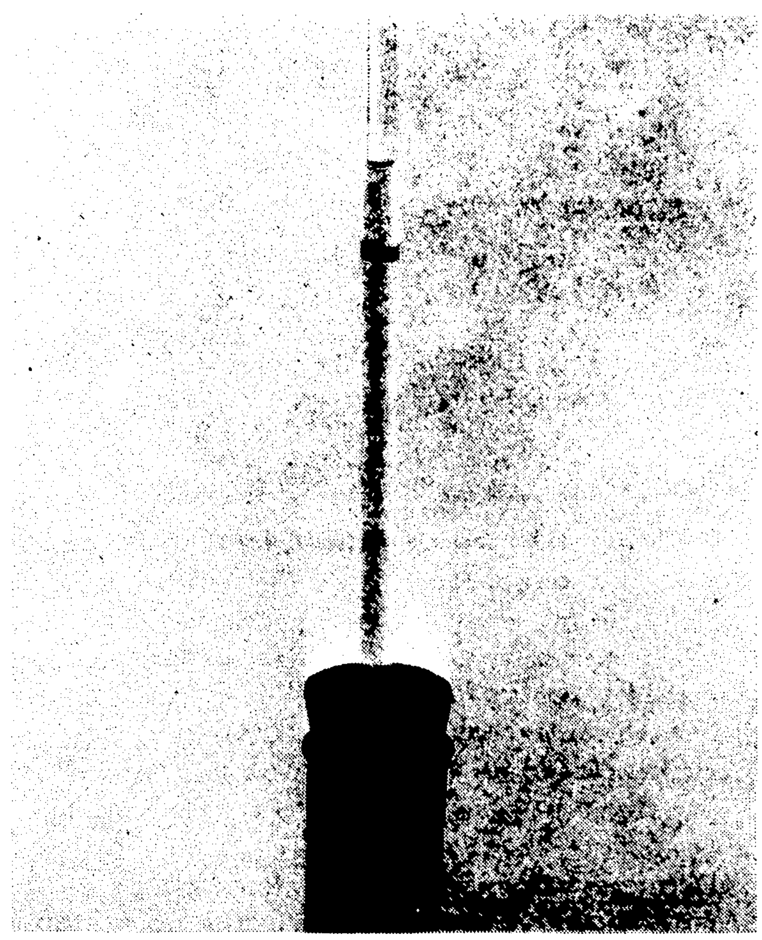

Fig. 7. Water level in tube after flask was placed in warm water

discussion with the individuals expressing the two divergent opinions there was 100 per cent agreement.

During the course of the selection procedure the question was raised "Does the sequence in which the demonstrations were performed affect the responses of the subjects?" A study was conducted to determine the answer.

A sixth-grade class of 30 subjects was selected as the population. The six subjects with the highest IQ in the class were randomly assigned to the six sequences possible utilizing three demonstrations. The six with the next highest IQ were assigned until all 30 subjects were assigned to one of the six different sequences. Thus, each sequence group included five subjects with a range of IQ from 95 to 128. A one-way analysis of variance was used to test the null hypothesis of no difference in subject's responses due to sequence. An alpha of .05 was chosen.

Table 1

Frequency of Classification of Subjects As Modelers or Nonmodelers When Submitted to a Variety of Sequences of Demonstrations, Arranged According to IQ Range

IQ Range	LGS	SGL	SLG	LSG	GSL	GLS
120-128	0	1	1	1	1	1
114-118	1	1	0	0	0	1
111-114	0	1	1	1	1	0
106-111	1	0	0	1	0	0
95-105	0	0	1	1	0	0
Total Modelers	2	3	3	4	2	2
$\bar{X}$	.4	.6	.6	.8	.4	.4

Modeler - 1 Nonmodeler - 0
Demonstrations: L - liquid; S - solid; G - gas

It is noted in Table 2 that no significant difference in responses exists due to variations in sequence of exposure to the demonstrations. The null hypothesis, therefore, cannot be rejected. Stratification of subjects according to intelligence accounted for a significant amount of response variance. This result was not unexpected.

Table 2

Summary Table For the Analysis of Variance of Data From the Sequence Study

Source	SS	df	MS	F	F (critical)
Treatments (between groups)	1.73	5	.35	1.94	2.71
Intelligence	2.20	4	.55	3.06	2.87
Error	3.54	20	.18		
Total	7.47	29			

The design adopted for the fourth-, fifth-, and sixth-grade population was a 2 x 3 x 3 fixed factorial that included four subjects per cell. (Table 3) The factors included were: grade level, treatment, and whether the subject was a model user (Modeler) or not a model user (Nonmodeler).

Table 3

2 x 3 x 3 Fixed Factorial Design of Investigation

	Grade	Treatment 0	Treatment 1	Treatment 2
Modeler	4			
	5			
	6			
Nonmodeler	4			
	5			
	6			

The design for the second and third grades was simpler since there were no Modelers in either grade. Only two cells per grade were needed to receive instruction utilizing the two different types of mechanical models, static and dynamic.

Since the main problem under investigation was the effectiveness of two types of models it was decided to have three treatment groups: Treatment 0—the group that received no instruction by the investigator; Treatment 1—the group that received instruction in which a static model was employed; and Treatment 2—the group that received instruction in which a dynamic model was employed.

SELECTION OF SAMPLE

In order to lend stability to the results of the treatment to be utilized it was decided to include a minimum of 12 Modelers and 12 Nonmodelers as the sample for each of the grade levels 4, 5, and 6.

Class rosters were secured for all fourth-, fifth-, and sixth-grade classrooms in Janesville, Wisconsin. Within each grade level the rosters were alphabetized after which each subject was assigned a number in chronological sequence starting with the beginning of the alphabet. This procedure was repeated for each grade level.

Since the trial testing experience had demonstrated that Nonmodelers were more common that Modelers it was decided that subjects would be tested until a total of 12 Modelers was identified at each of the grade levels 4, 5, and 6. Subjects to be tested were selected by the investigator using a table of random numbers.

During the testing procedure in which the 12 Modelers were identified, records were maintained of the Nonmodelers identified. The 12 Nonmodelers at each grade level were randomly selected from the list for the respective level.

In order to impartially assign subjects to the three treatment groups the 12 Modelers were listed alphabetically by last name and randomly assigned. This procedure was repeated in the assignments of the 12 Nonmodelers for each grade level.

The procedures initially employed in selecting subjects from Grades 2 and 3 were identical to those employed in Grades 4, 5, and 6. A modification of the procedure was indicated by the fact that no Modelers were isolated as a result of pretesting 16 second graders and 19 third graders. It was impossible to have a sample of Modelers for these levels and thus a modification in the method of treating the data was in order.

The concern for the subjects in Grades 2 and 3 was the same as that for the Nonmodeler groups in Grades 4, 5, and 6; the relative effectiveness of the two types of models in teaching the idea the particle nature of matter. Because it was not known whether the concept could be taught at all, at this level the Treatment 0 group was eliminated from the design. It was assumed that if any or all gave acceptable explanations following the period of instruction the effect would be the result of the instruction.

The eight subjects from each of Grades 2 and 3 were selected at random from the populations of 16 and 19, respectively, that had been pretested.

TREATMENTS

The phenomena selected to be observed and explained by the subjects using the particle nature of matter were to be physical, that is, the changes were to be limited to expansion, contraction, solution, diffusion, and change of phase. Apropos to this decision two types of models were selected—one a static model and the other a dynamic model.

The static models consisted of (1) two embroidery hoops of different diameters and a number of pith balls, and (2) a beaker of marbles and a beaker of BB shot. (See Figures 8 and 9.) The dynamic model consisted of a transparent plastic cylinder six inches in diameter with a piece of rubber dam stretched over one end. A metal washer was fastened to the center of the rubber dam and centered over a Thompson coil. Pith balls were placed in the cylinder on the rubber dam. The motion of the pith balls was varied by means of

Fig. 8. Embroidery hoops

Fig. 9. Beaker of marbles and beaker of BB shot

increasing or decreasing the intensity of the 60 cycle magnetic field formed by the coil. (See Figure 10.)

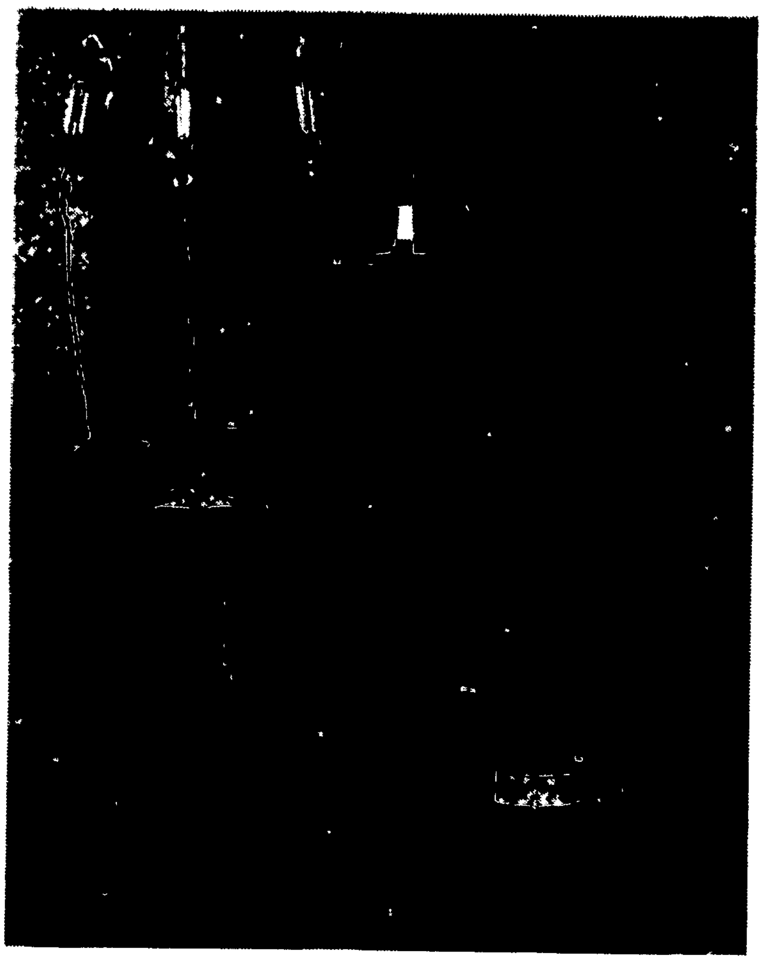

Fig. 10. Dynamic model

A. Treatment 0. Subjects in this group received no instruction from the investigator. Teachers at the several levels within the Janesville school system involved with this project were encouraged not to teach any aspect of the concept of the particle nature of matter during the experimental period of three months.

B. Treatments 1 and 2. Each subject in these treatment groups was given direct instruction by the investigator for a period of 15 minutes. The sequence of the instructional period was uniform and as follows:

1. A demonstration was performed in which the total volume of two liquids when mixed was less than the arithmetic sum of the separate volumes prior to mixing (alcohol and water). (See Figures 11, 12, and 13.)

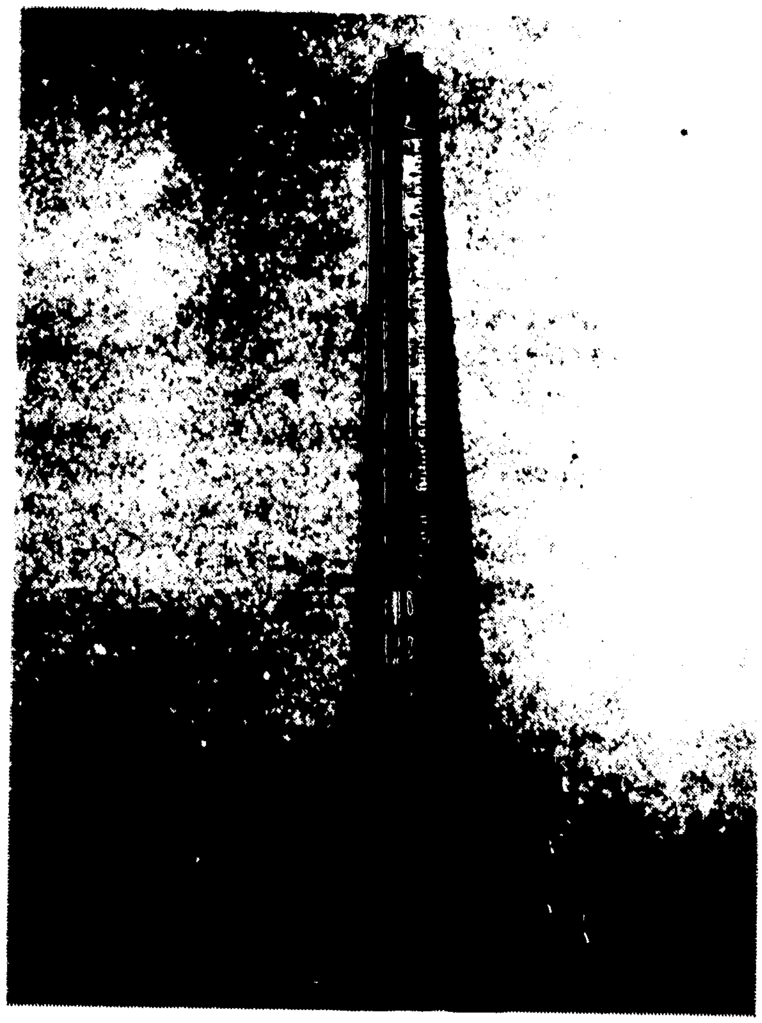

Fig. 11. Colored alcohol layered on water in an enclosed tube

The investigator posed questions as noted previously—"What happened?" "What could the alcohol and water be like for this to happen?" etc.

2. Since the responses of all subjects in the groups to receive Treatments 1 and 2 were unsatisfactory, a period of instruction was initiated.

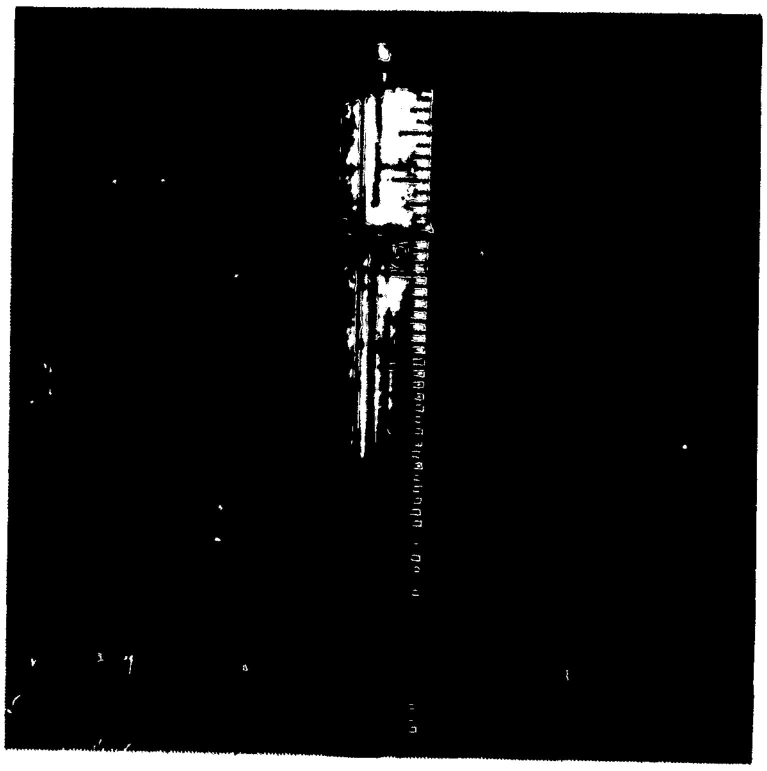

Fig. 12. Level of liquids in tube prior to mixing

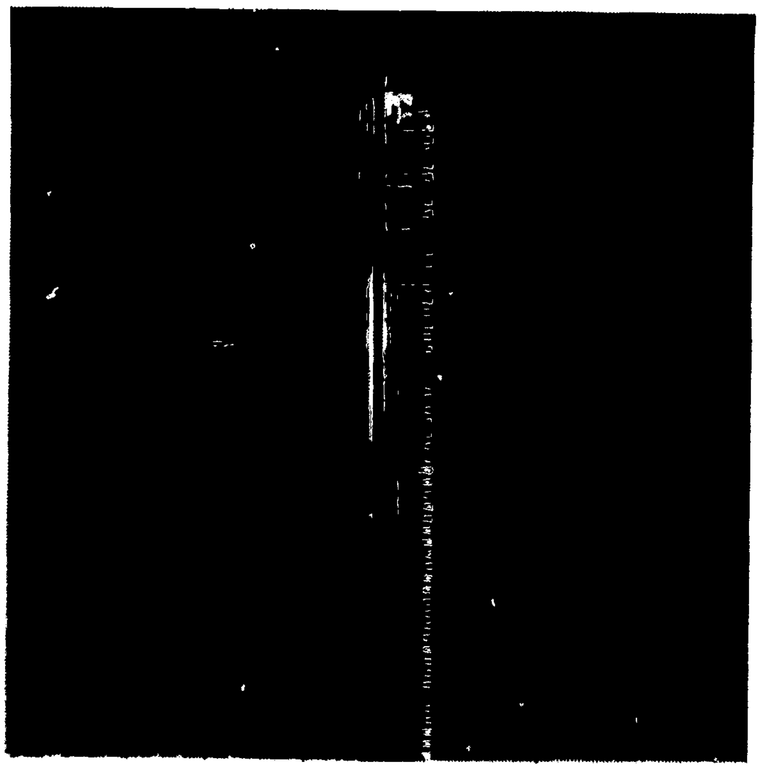

Fig. 13. Level of liquids in tube after mixing

a. Treatment 1. The instructional period was carried on by the investigator utilizing a static model. In this case, the model consisting of a beaker of marbles and a beaker of BB shot was used. The marbles represented the alcohol and the BB shot the water. When BB shot were poured over the marbles it was analogous to the mixing of alcohol and water. The reduction in total volume was noted by the subject. Attention was directed to the model and how it helped to explain the alcohol and water phenomenon. (See Figures 14 and 15.)

b. Treatment 2. The instructional period was carried on by the investigator utilizing a dynamic mechanical model. This model was the cylinder with the rubber dam over one end. A layer of styrofoam balls each 3/4" in diameter was formed in the cylinder and the subjects observed the spaces between the balls. The rubber was caused to vibrate at different rates by varying the intensity of the 60 cycle magnetic field. This movement caused the styrofoam balls to bounce around. After the subjects had observed the balls in motion and the instructor had pointed out the analogy between the balls and particle idea of matter, the Variac was turned off. A layer of pith balls was added to the cylinder so there were now two types of particles and the subjects were told that this condition was analogous to the water and alcohol demonstration they had observed. The coil was again energized and the results observed by the subjects.

Fig. 14. Beaker of marbles representing molecules of alcohol

When the Variac was turned off, the subjects observed that the large and small balls were mixed up and the space between the large balls were now filled with the smaller balls. (See Figure 10 for equipment.)

3. The ball and ring demonstration was repeated. The subjects observed that the ball

Fig. 15. BB shot mixed with marbles representing molecules of water and alcohol

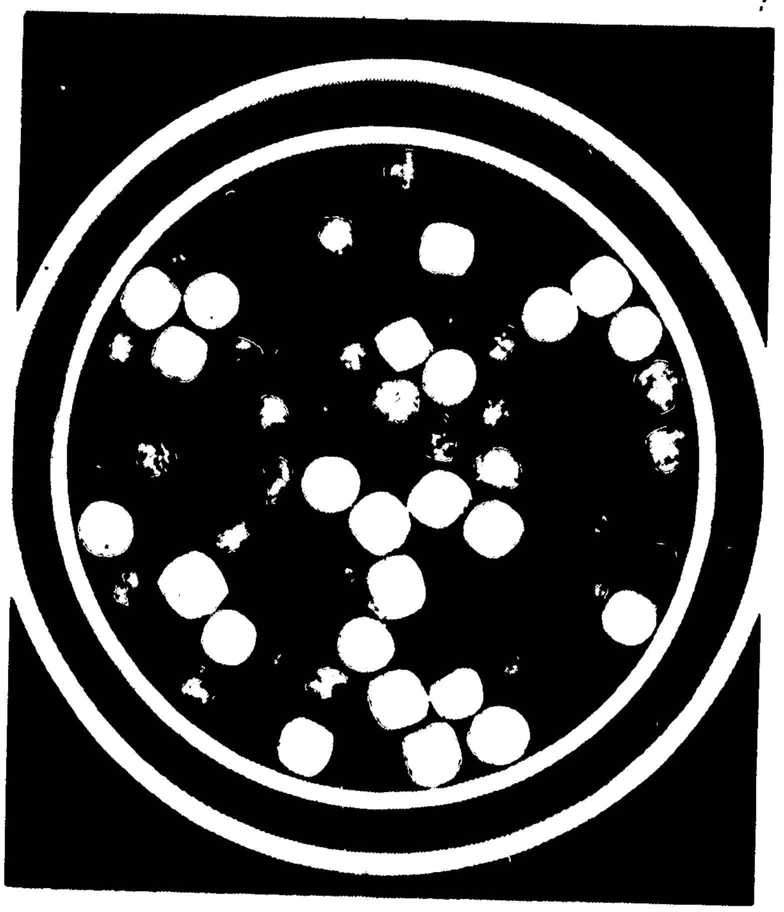

Fig. 16. Pith balls covering area smaller hoop

passed through the ring when both were at room temperature, but not after the ball had been heated. The investigator again posed the questions "What happened?" and "What could the ball be like in order for this to happen?" (See Figures 1 and 2.)

4. Although the majority of the subjects classified as Modelers and a few of those classified as Nonmodelers in the two treatment groups responded in a way that indicated some acquaintance with the particle idea of matter only three within the population of 48 included the kinetic theory as a means of explaining expansion of a solid. Therefore the period of instruction for all in Treatment Groups 1 and 2 was continued.

a. Treatment 1. The investigator utilized two embroidery hoops and pith balls as the static model in the instructional sequence. The hoops were placed on a paper and the central area of the smaller hoop was covered with pith balls. This was analogous to the ball at room temperature. Hoop Number 1 was replaced with the larger hoop Number 2, but the number of pith balls remained unchanged. The balls were spread out so that the area again appeared to be filled. The investigator explained that this was an idea to help explain expansion of a solid. (See Figures 16 and 17.)

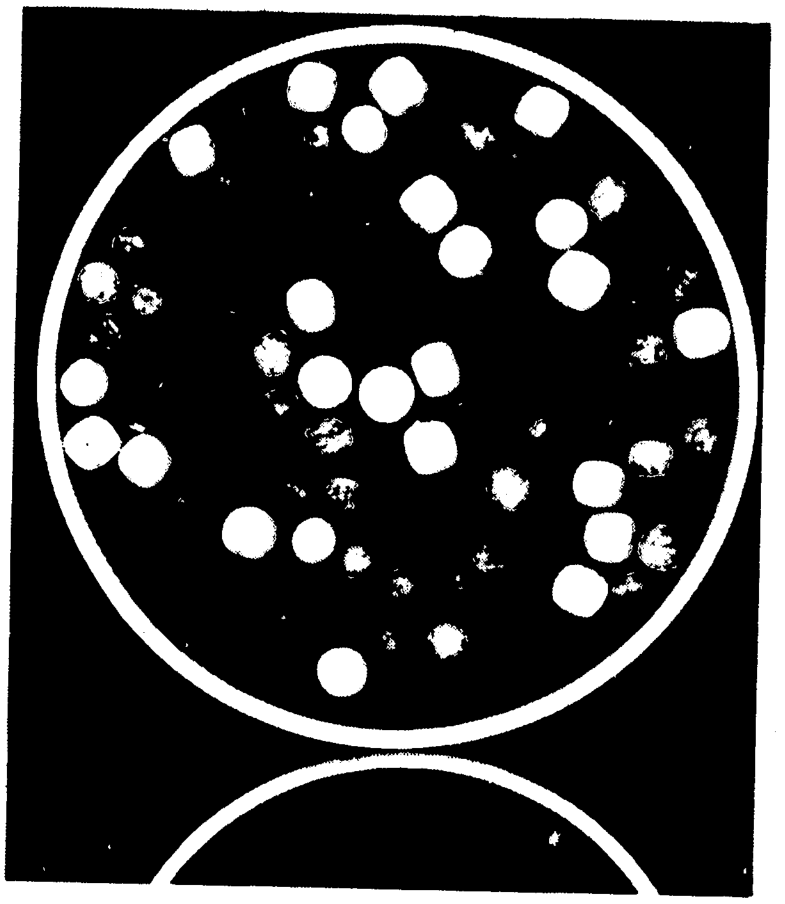

Fig. 17. Pith balls spread out in larger hoop

b. Treatment 2. The dynamic model utilized was the cylinder, rubber dam, Variac combination used in the previous instructional period. A layer of pith balls smaller in area than the area of the cylinder opening was placed on the rubber dam. The subjects observed the open area around the pith balls. The coil was energized causing the balls to vibrate and spread out and to finally become distributed over the rubber dam covering the end of the cylinder. The observations of this phenomenon were made by the subjects and the analogy to the expansion of the solid was described by the instructor. (See Figure 10.)

EVALUATION

The effects of the periods of instruction utilizing no treatment, the static model and the dynamic model were measured directly; the subjects observed the phenomenon and then gave the explanation.

The criteria for the items to be included as the posttest were:

A. The phenomenon must be amenable to demonstration with simple equipment.

B. The phenomenon must not be a duplication of a teaching situation.

C. The phenomenon must not be a duplication of one used in the sample selection procedure.

D. The phenomenon to be explained must be physical in nature.

E. The phenomenon must be explainable through the use of the particle idea of matter.

F. The phenomena must be of different levels of sophistication; some must be explainable utilizing the static model and some the dynamic model.

G. The sequence of the test items should be from immediate experience, recall, to transfer, to invention.

Eight test demonstrations were selected and arranged utilizing these criteria:

1. A colorless liquid was poured into a 10 mm. glass tube 50 cm. long until the tube was one half filled. A red liquid was then added to the tube until the tube was filled to a predetermined level. The subjects observed the operation of filling and marked the level of the liquid on the tube. The contents of the tube were then mixed by inverting the tube. The liquid level was marked following the mixing. (See Figures 11, 12, and 13.)

2. Ball and ring. A brass ball and a brass ring were so machined that the ball would pass through the ring only when considerable force was applied when both were at room temperature. After heating the ring the ball passed through freely. (See Figures 18 and 19.)

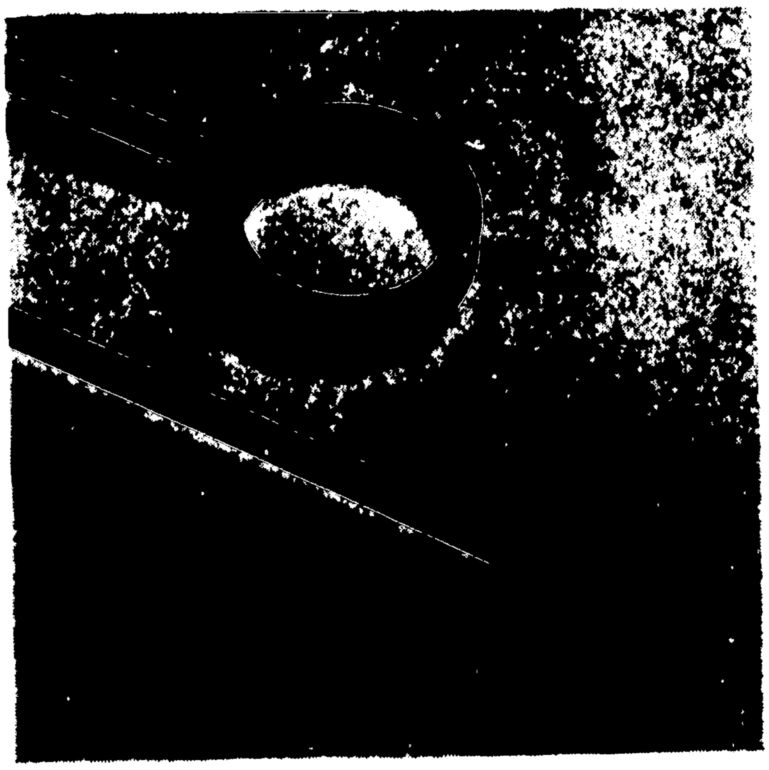

Fig. 18. Ball and ring apparatus at room temperature

Fig. 19. Ring being heated by a propane burner

3. A teaspoonful of sugar was added to 100 ml. of water in an erlenmeyer flask and agitated to speed up solution. The subjects collected samples of the mixture from many parts of the container by means of a straw and tasted the sample. (See Figure 20.)

4. The level of the mercury column in a thermometer was noted. The bulb of the thermometer was then heated by placing it in warm water. The change in the length of the mercury column was noted. (See Figure 21.)

Fig. 20. Flask with straw in water prior to sugar being added to the water

Fig. 21. Thermometer held in a beaker of warm water

5. A small quantity of water was placed in a pyrex test tube and heated to evaporation. (See Figure 22.)

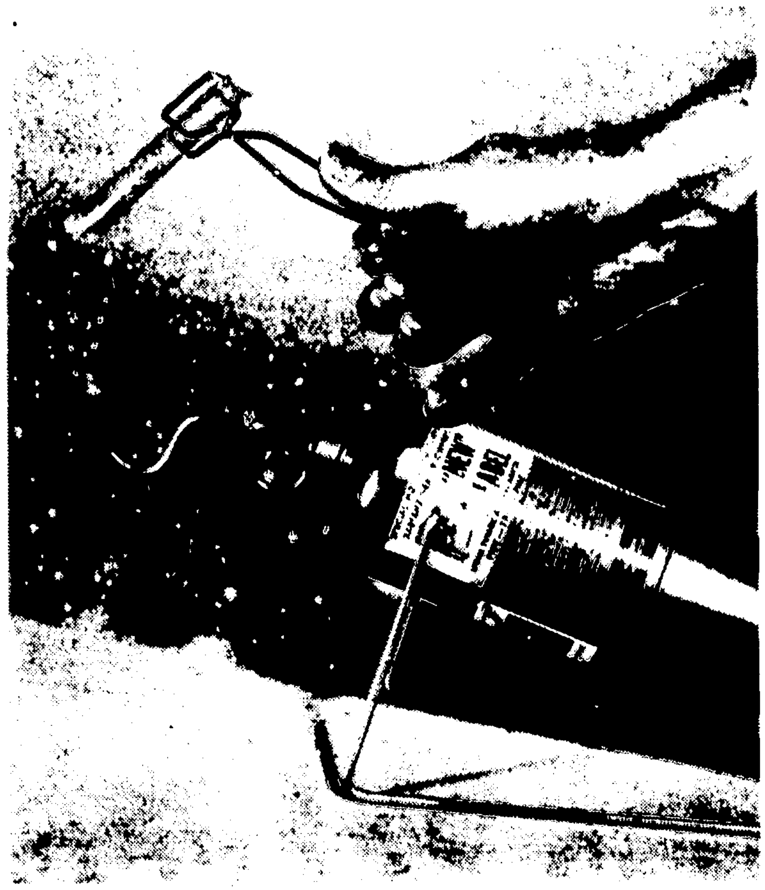

Fig. 22. Water in test tube being heated over a propane burner

6. The steam from a beaker of boiling water was allowed to strike a cool aluminum pan so that the result of condensation could be observed. (See Figure 23.)

Fig. 23. Beaker of hot water with an aluminum pan set above the water level

7. A drop of food coloring was placed in a 250 ml. beaker of warm water. The diffusion of the color was observed. (See Figures 24 and 25.)

Fig. 24. Drop of food coloring just added to a beaker of warm water

Fig. 25. Diffusion of food coloring 15 seconds after being added to warm water

8. A small piece of dry ice was placed in an aluminum pan. The sublimation of the dry ice was observed. (See aluminum pan in Figure 23.)

The questions asked by the investigator following each demonstration were: "What did you see happen?" and "What do you think the material is like so this can happen?" All responses were tabulated on paper and the entire process was tape recorded.

Items 1 and 2 in the test sequence were recall, 3 and 4 were transfer, and 5, 6, 7, and 8 involved invention.

All testing sequences were completed within two days of the teaching sequence and all treatments and testing were carried on by the investigator.

The level of understanding of a subject was assumed to be directly related to the number of phenomena for which he supplied acceptable explanations.

PILOT STUDY

Prior to the decision to use the procedures here described, a pilot study was completed. This resulted in slight modifications of the initially intended procedure.

The testing through interview and demonstration clinical technique was utilized successfully with 100 children; 20 each in Grades 2 through 6. During this trial study 20 demonstrations were used, some were modified and some were eliminated because of such factors as reliability of results, danger, time required, etc.

The demonstrations selected for the pretest met the criteria of (1) clarity, (2) simplicity, (3) physical change, (4) involved changes in the three phases of matter, and (5) safety.

The demonstrations selected for the final test met the criteria stated on page 16.

ANALYSIS OF DATA

The principal method for analyzing the data was the analysis of variance (ANOVA). An alpha of .05 was previously chosen for this analysis. A 1604 computer at the University of Wisconsin Computing Center with the ANOVA program was used for the treatment of the data. Scheffe post hoc tests were conducted to determine whether noted differences were significant. Correlations between test score, age level, grade level of enrollment, mathematics achievement score on the Stanford Achievement test and science achievement score on the Stanford Achievement test were calculated using the Stat I program on the 1604 computer. The data secured from the second- and third-grade subjects were analyzed by the use of two sample t-tests to compare the means of cell groups.

IV
RESULTS

INTRODUCTION

The results of the investigation are presented in two sections; the phase concerned with Grades 4, 5, and 6 and the phase concerned with Grades 2 and 3. Within each section the results are presented in the following order: (1) the selection process; (2) the test; and (3) the analysis of data.

THE SELECTION PROCESS; GRADES 4-6

The process of identifying 12 Modelers per grade involved the pretesting of 105 children in Grades 4, 5, and 6. The numbers ranged from 41 in Grade 4 to 31 in Grade 6.

Table 4

Number of Subjects in Grades 4, 5, and 6 Tested in Selecting Twelve Modelers

Grade	No. of Subjects	No. of Modelers	No. of Nonmodelers
4	41	12	29
5	33	12	21
6	31	12	19
Total	105	36	69

The selection of the sample of 12 Nonmodelers per grade from the 69 identified resulted in a total distribution of boys to girls of 15:21; the same ratio as that in the Modeler group.

The ratio of boys to girls within the Modeler group at the three grade levels is 5:7 while that within the Nonmodeler group varies from 4:8 to 5:7. No attempt was made to have equal numbers of each sex in any two grades.

Table 5

Distribution of Population of Modelers and Nonmodelers According to Sex and Grade Level

Grade	Modelers		Nonmodelers	
	Boys	Girls	Boys	Girls
4	5	7	5	7
5	5	7	4	8
6	5	7	6	6
Total	15	21	15	21

THE TEST; GRADES 4-6

Since each subject gave one explanation for each demonstration it was possible to tabulate the responses to the eight test demonstrations and to assign a score of 32 to the total test for each group of four subjects, or a score of eight to a single subject if he gave acceptable explanations to the eight demonstrations.

A. Examination of Tables 6 and 7, concerned with Grade 4, reveals the following:

1. Subjects who were Modelers prior to the experimental period (Treatment 0) continued to use some acceptable models in explaining the phenomena included in the eight demonstrations. Although the four members of the group used acceptable models in explaining Demonstration 3 (solution of sugar in water), the total score for the eight demonstrations was only 11. There were three phenomena demonstrated for which no explanations were given and two that were acceptably explained by only one subject each.

Further evidence that the Modelers continue to be Modelers individually as well as

Table 6

Posttest Results for Grade 4 Arranged by Group, Treatment, and Demonstration

M=Modeler N=Nonmodeler	Treatment	Score	Demonstration 1	2	3	4	5	6	7	8
M	0	2		x	x					
M	0	4		x	x	x			x	
M	0	1			x					
M	0	4		x	x			x	x	
N	0	1			x					
N	0	0								
N	0	0								
N	0	0								
M	1	4	x	x	x	x				
M	1	7	x	x	x	x	x	x	x	
M	1	7	x	x	x	x	x	x	x	
M	1	6	x	x	x	x		x		x
N	1	2		x	x					
N	1	5	x	x			x		x	x
N	1	3	x	x	x					
N	1	2		x	x					
M	2	6	x	x	x			x	x	x
M	2	8	x	x	x	x	x	x	x	x
M	2	6	x	x	x	x	x		x	
M	2	7	x	x	x	x	x	x	x	
N	2	5	x	x	x	x			x	
N	2	5	x	x		x	x		x	
N	2	3	x	x					x	
N	2	6	x	x	x	x	x		x	
	Total	94	14	19	18	11	8	7	13	4

Table 7

Frequency of Acceptable Explanations by Treatment and Group, Grade 4

Demon-stration	Treatment 0		Treatment 1		Treatment 2	
	Modeler	Nonmodeler	Modeler	Nonmodeler	Modeler	Nonmodeler
1	0	0	4	2	4	4
2	3	0	4	4	4	4
3	4	1	4	3	4	2
4	1	0	4	0	3	3
5	0	0	2	1	3	2
6	1	0	3	0	3	0
7	2	0	2	1	4	4
8	0	0	1	1	2	0
Total	11	1	24	12	27	19

collectively is found in the fact that the four Modelers in the Treatment 0 group gave acceptable explanations for at least one phenomenon demonstrated and two gave acceptable explanations for four phenomena.

2. Subjects who were Nonmodelers prior to the experimental period (Treatment 0), continued to provide unacceptable explanations of physical phenomena. There was only one subject who gave an acceptable explanation to as many as one demonstrated phenomenon. The score for the Nonmodeler-Treatment 0 group was one.

3. Subjects classified as Modelers who received Treatment 1 (Static Model) earned a score of 24 indicating a gain of 13 points. The higher score of the Modeler-Treatment 1 group may be attributed to the effect of the treatment as indicated by the analysis of variance. (Table 13.)

There were four phenomena demonstrated for which all members of the Modeler-Treatment 1 group gave acceptable explanations and only for the phenomenon in Demonstration 8 was there a single acceptable explanation.

When the achievement of individuals in the Modeler-Treatment 1 group is considered, it is found that two subjects gave acceptable explanations to seven of the eight phenomena demonstrated, one subject gave acceptable explanations to six phenomena and only one gave acceptable explanations to as few as four.

4. The Nonmodelers who received Treatment 1 earned a total score of 12 which was 11 points higher than that earned by the Nonmodelers who received Treatment 0. This difference between the means of .25 and 3.00 for Treatment 0 and Treatment 1 groups, respectively, may be attributed to the effect of the treatment. (Table 13.)

The nature of the Nonmodeler-Treatment 1 group level of achievement is evident from the following: one phenomenon was acceptably explained by the four subjects, one by three, one by two, three by one each, and two were without explanations.

Individual achievement within the group ranged from five to two acceptable explanations given. Subjects with achievement scores of two or three limited their explanations to phenomena included in Demonstrations 1, 2, and 3.

5. The fact that the Modeler-Treatment 2 group earned a score 16 points higher than that earned by the Modeler-Treatment 0 group may be attributed to the difference in treatment, however, the three-point difference between the Modeler-Treatment 1 and Modeler-Treatment 2 groups is not significant. (Table 14.)

There were four phenomena demonstrated to which all subjects in the Modeler-Treatment 2 group gave acceptable explanations, three to which three of the four gave acceptable explanations, and none that were not acceptably explained by two or more subjects.

Individual scores earned by members of the Modeler-Treatment 2 group were the highest in Grade 4; no one earned a score below six.

6. The total score earned by the Nonmodeler-Treatment 2 group was higher than that earned by the Nonmodeler-Treatment 0 and the Nonmodeler-Treatment 1 groups but was lower than that earned by the Modeler-Treatment 1 and the Modeler-Treatment 2 groups. There were three phenomena demonstrated to which the four members of the group gave acceptable explanations; however, there was also one for which no one of the four gave acceptable explanations.

The difference between the Nonmodeler-Treatment 2 and the Nonmodeler-Treatment 0 groups may be attributed to the experimental treatment.

When individual achievement is examined, it is found that no one of the subjects earned a score of eight. The range was from three to six with only one six appearing.

7. --Summary. The scores earned by subjects at the fourth-grade level indicate that:

a. Subjects at this level who do not use acceptable models can be taught to use acceptable models to explain physical phenomena involving the particle theory of matter;

b. Subjects in Grade 4 who already use acceptable models including the particle theory of matter to explain physical phenomena can improve this ability as a result of proper learning experiences;

c. An analogous dynamic mechanical model is not superior to an analogous static mechanical model in teaching subjects at the Grade 4 level to use acceptable models to explain phenomena involving the particle theory of matter.

B. Study of the data for Grade 5 included in Tables 8 and 9 indicates the following:

1. Subjects (Modeler-Treatment 0 group) in Grade 5 who used acceptable models during the initial testing sequence continued to use them in a limited way during the final testing sequence as indicated by a group score of 12. Again, as at the Grade 4 level, the phenomenon demonstrated in Item 3 was ac-

Table 8

Posttest Results for Grade 5 Arranged by Group, Treatment, and Demonstration

M=Modeler N=Nonmodeler	Treatment	Score	Demonstration 1	2	3	4	5	6	7	8
M	0	3		x	x	x				
M	0	4		x	x	x	x			
M	0	3		x	x		x			
M	0	2			x		x			
N	0	1			x					
N	0	0								
N	0	1			x					
N	0	0								
M	1	7	x	x	x	x	x		x	x
M	1	8	x	x	x	x	x	x	x	x
M	1	7	x	x	x	x	x	x	x	
M	1	3	x	x	x					
N	1	4	x	x		x			x	
N	1	3	x	x	x					
N	1	3	x	x	x					
N	1	4	x	x		x			x	
M	2	5	x	x	x	x	x			
M	2	6	x	x	x	x	x		x	
M	2	8	x	x	x	x	x	x	x	x
M	2	8	x	x	x	x	x	x	x	x
N	2	3	x	x	x					
N	2	3	x	x		x				
N	2	3	x	x	x					
N	2	4	x	x	x				x	
	Total	93	16	19	19	12	10	4	9	4

Table 9

Frequency of Acceptable Explanations by Treatment and Group, Grade 5

Demon-stration	Treatment 0		Treatment 1		Treatment 2	
	Modeler	Nonmodeler	Modeler	Nonmodeler	Modeler	Nonmodeler
1	0	0	4	4	4	4
2	3	0	4	4	4	4
3	4	2	4	2	4	3
4	2	0	3	2	4	1
5	3	0	3	0	4	0
6	0	0	2	0	2	0
7	0	0	3	2	3	1
8	0	0	2	0	2	0
Total	12	2	25	14	27	13

ceptably explained by the four members of this group. In addition there were two other phenomena demonstrated that were acceptably explained by as many as three members of the group and four phenomena that were not explained by any.

The range in number of phenomena acceptably explained ranged from two to four with all subjects being successful in explaining at least two.

2. The score of two for the Nonmodeler-Treatment 0 group indicates that the subjects who were Nonmodelers during the selection process continued to be Nonmodelers during the testing process. Acceptable explanations were given by two subjects to the phenomenon demonstrated in Item 3; the other phenomena were not explained by any of the members of the Nonmodeler-Treatment 0 group.

3. The score of 25 earned by the Modeler-Treatment 1 group is 13 points higher than that earned by the Modeler-Treatment 0 group. When these data are treated utilizing analysis of variance techniques, it is noted that the difference may be attributed to the treatment effect. (Table 13.)

The phenomena demonstrated in Items 1, 2, and 3 were acceptably explained by the four and those demonstrated in Items 4, 5, 6, 7, and 8 were acceptably explained by a minimum of two and a maximum of three members of the Modeler-Treatment 1 group. The degree of success of individual subjects here is indicated by the range of the scores from eight to three with three of the four earning scores of seven or above.

4. The Nonmodeler-Treatment 1 group earned a total score of 14 which is 12 points higher than that of the Nonmodeler-Treatment 0 group but only two points higher than the Modeler-Treatment 0 group. The difference in scores between the Nonmodeler-Treatment 0 and Nonmodeler-Treatment 1 groups may be attributed to the differences in treatment.

The degree of success of individual subjects, as indicated by individual scores, is relatively uniform (two earned three and two earned four); however, there was some variation in the phenomena acceptably explained. All subjects were successful in explaining the phenomena demonstrated in Items 1 and 2 and only two each acceptably explained the phenomena in Items 5, 6, and 8.

5. The group score of 27 for the Modeler-Treatment 2 group was higher than that earned by any other group in Grade 5. In this case the phenomena demonstrated in Items 1 through 5 were acceptably explained by the four members of the group.

The difference of 15 between the total scores earned by the Modeler-Treatment 0 and Modeler-Treatment 2 groups may be attributed to the difference in treatments given the two groups.

Individual scores within the Modeler-Treatment 2 group range from two subjects with eight acceptable explanations to one with five. The average individual score of 6.75 is higher than that in any other group in Grade 5. The mean score for this group is identical to that for the comparable group in Grade 4.

6. The total score earned by the Nonmodeler-Treatment 2 group is 13 while that of the comparable group with Treatment 1 is 14. This difference in scores is negligible, while the difference between this group and the Nonmodeler-Treatment 0 group is indicated to be due to the effect of the treatment. (Table 13.) The total score of 13 for the Nonmodeler-Treatment 2 group is six points lower than that of the comparable group in Grade 4.

The individual scores earned are relatively uniform consisting of three with three and one with four. Only two subjects gave acceptable explanations for an item above Item 3.

7. Summary. The scores earned by subjects at the fifth-grade level indicate that:

a. Subjects at this grade level who do not use acceptable models can be taught to use acceptable models to explain physical phenomena involving the particle theory of matter;

b. Subjects in Grade 5 who already use acceptable models involving the particle theory of matter to explain physical phenomena can improve this ability as a result of proper learning experiences;

c. An analogous dynamic mechanical model is not superior to an analogous static mechanical model in teaching subjects of the Grade 5 level to use acceptable models to explain phenomena involving the particle theory of matter.

C. It is noted from the data related to Grade 6 included in Tables 10 and 11 that:

1. The subjects in Grade 6 who used acceptable models in explaining physical phenomena during the selection process and who received no instruction continued to use acceptable models in their explanations of the physical phenomena demonstrated. The Modeler-Treatment 0 group score of 20 was higher than that for comparable groups in Grades 4 and 5. All four of the subjects provided acceptable explanations for two of the demonstrations and three provided acceptable explanations for three demonstrations. There

Table 10

Posttest Results for Grade 6 Arranged by Group, Treatment, and Demonstration

M=Modeler N=Nonmodeler	Treatment	Score	Demonstration 1	2	3	4	5	6	7	8
M	0	4		x	x	x			x	
M	0	6		x	x	x	x		x	x
M	0	4		x		x	x		x	
M	0	6		x	x	x	x	x		x
N	0	1				x				
N	0	2	x		x					
N	0	0								
N	0	1			x					
M	1	5	x	x	x	x			x	
M	1	4	x		x	x				x
M	1	8	x	x	x	x	x	x	x	x
M	1	6	x	x	x	x	x		x	
N	1	3	x	x	x					
N	1	2	x	x						
N	1	4	x	x		x		x		
N	1	5	x	x	x		x		x	
M	2	8	x	x	x	x	x	x	x	x
M	2	5	x	x	x	x			x	
M	2	5		x		x	x		x	x
M	2	7	x	x	x	x	x	x	x	
N	2	5	x	x	x	x			x	
N	2	5	x	x	x	x			x	
N	2	5	x	x	x	x			x	
N	2	5	x	x	x	x			x	
	Total	106	16	19	18	18	9	5	15	6

Table 11

Frequency of Acceptable Explanations by Treatment and Group, Grade 6

Demonstration	Treatment 0		Treatment 1		Treatment 2	
	Modeler	Nonmodeler	Modeler	Nonmodeler	Modeler	Nonmodeler
1	0	1	4	4	3	4
2	4	0	3	4	4	4
3	3	2	4	2	3	4
4	4	1	4	1	4	4
5	3	0	2	1	3	0
6	1	0	1	1	2	0
7	3	0	3	1	4	4
8	2	0	2	0	2	0
Total	20	4	23	14	25	20

was only one phenomenon demonstrated for which no acceptable explanation was given.

The range of scores in the Modeler-Treatment 0 group was from four to six with two subjects receiving a score of four and two receiving a score of six. An examination of the types of explanations given by the subjects in this group during the initial selection test revealed that two of the subjects had used explanations involving the motion of particles. Assignment to the Treatment 0 group was the result of the random selection procedure employed. Three of the subjects in the group had supplied model explanations for all three of the phenomena demonstrated in the selection process.

2. The score of four earned by the Nonmodeler-Treatment 0 group reveals that the subjects who were classified as Nonmodelers continued in that pattern during the model usage test. Acceptable explanations were provided for only three of the eight test phenomena demonstrated.

One subject provided acceptable explanations for two items, two subjects provided acceptable explanations for one item each, and the fourth subject provided no acceptable explanations.

3. The difference in levels of achievement between the Modeler-Treatment 0 and the Modeler-Treatment 1 groups is three points and may not be attributed to differences in treatment.

The range of individual scores within the Modeler-Treatment 1 group was four to eight; one subject provided acceptable explanations for all eight phenomena demonstrated. Each of the four subjects supplied acceptable explanations for the phenomena demonstrated in Items 1, 3, and 4 and three subjects supplied acceptable explanations for phenomena demonstrated in Items 2 and 7.

4. The score of 14 for the Nonmodeler-Treatment 1 group was 10 points higher than that for the Nonmodeler-Treatment 0 group, a difference that may be attributed to the difference in treatment. (Table 13.)

All of the subjects in the Nonmodeler-Treatment 1 group gave acceptable explanations for the first two phenomena, two subjects gave acceptable explanations for the phenomenon in Item 3 with single acceptable explanations given for the phenomena in Items 4, 5, 6, and 7. No acceptable explanations were provided for the phenomenon in Item 8.

The range of individual scores for the Nonmodeler-Treatment 1 group was from two to five and no consistency was noted.

5. The two-point difference in scores between the Modeler-Treatment 2 group (25) and the Modeler-Treatment 1 group (23) may not be attributed to differences in treatment.

All items included in the test sequence were acceptably explained by at least two subjects, three items by three subjects, and three items by all four subjects in the Modeler-Treatment 2 group. The achievement of the individual subjects as indicated by the scores ranges from five to eight, however, there was only one eight and there were two fives.

6. The Nonmodeler-Treatment 2 group achieved a score of 20 which was 16 points higher than that achieved by the Nonmodeler-Treatment 0 group; a difference that may be attributed to the difference in treatment. (Table 13.)

The subjects in the Nonmodeler-Treatment 2 group gave acceptable explanations for the same five phenomena during the final evaluation period, Items 1, 2, 3, 4, and 7. None of the subjects supplied acceptable explanations for the phenomena in Items 5, 6, and 8. The scores achieved by subjects in this group were the most uniform of any group tested.

7. Summary. The scores earned by the subjects at the sixth-grade level indicate that:

a. Subjects at this level who do not use acceptable models can be taught to use such models to explain physical phenomena involving the particle theory of matter;

b. Subjects in Grade 6 who already use acceptable models involving the particle theory of matter to explain physical phenomena do not improve this ability significantly as a result of instruction;

c. An analogous dynamic mechanical model is not superior to an analogous static mechanical model in teaching subjects at the level of Grade 6 to use acceptable models to explain physical phenomena involving the particle theory of matter.

D. Summary of the data for the individual grades, Tables 6 through 11.

1. Subjects in Grades 4, 5, and 6 who did not use acceptable nonanimistic nonmagical models in explaining physical phenomena during the initial selection process continued to explain physical phenomena in the same manner when no instruction was provided.

2. Subjects in Grades 4, 5, and 6 who used acceptable nonanimistic nonmagical models in explaining physical phenomena during the selection process continued to use such models when no instruction was provided.

3. Subjects in Grades 4, 5, and 6 who did not use acceptable nonanimistic nonmagical models in explaining physical phenomena during the selection process learned to use acceptable models when provided with a period of appropriate instruction.

4. Subjects in Grades 4 and 5 who used acceptable nonanimistic nonmagical models in explaining physical phenomena during the selection process significantly improved their abilities to use acceptable models when provided with a period of appropriate instruction.

5. Subjects in Grade 6 who used acceptable nonanimistic nonmagical models in explaining physical phenomena during the selection process did not significantly improve their abilities to use acceptable models when provided with a period of appropriate instruction.

6. Subjects in Grades 4, 5, and 6 who used acceptable nonanimistic nonmagical models to explain physical phenomena prior to instruction achieved higher levels than did subjects who did not use acceptable models prior to instruction when both were given equal periods of appropriate instruction.

7. Within Grades 4, 5, and 6 the use of an analogous dynamic mechanical model was not significantly superior to the use of an analogous static mechanical model in teaching subjects to use acceptable models in explaining physical phenomena involving the particle nature of matter.

ANALYSIS OF DATA; GRADES 4-6

In order to determine which of the factors of grade level, treatment, and previous use of acceptable models attributed to the results of test differences a 2 x 3 x 3 fixed factorial design was used. Assignment of the four subjects to each of the cells within the Modeler and Nonmodeler groups was random. The mean scores achieved by each group are given in Table 12, and each score must be considered relative to the possible score of eight.

Table 12

Mean Scores Arranged According to Grade Level, Treatment, and Model Using Ability of the Subjects

		Treatment		
	Grade	0	1	2
Modeler	4	2.75	6.00	6.75
	5	3.00	6.25	6.75
	6	5.00	5.75	6.25
Nonmodeler	4	0.25	3.00	4.75
	5	0.50	3.50	3.25
	6	1.00	3.50	5.00

When analysis of variance techniques were applied to these data, it was found that:

1. The difference in scores between groups receiving Treatment 1 or Treatment 2 and those receiving Treatment 0 was significant and may be attributed to the nature of the treatment.

Table 13

Summary Table for the Analysis of Variance With an Alpha of .05

Source	SS	df	MS	F	F (critical)
Treatment	149.528	2	74.764	50.62	3.17
Modeler-Nonmodeler	125.347	1	125.347	84.87	4.02
Grade	4.361	2	2.181	1.48	3.17
T x (M-N)	1.694	2	0.847	0.57	3.17
T x G	9.139	4	2.285	1.55	2.55
(M-N) x G	0.694	2	0.347	0.24	3.17
T x (M-N) x G	8.139	4	2.035	1.38	2.55
Error (within)	79.750	54	1.477		
Total	378.632	71			

2. The scores earned by the Modeler group were significantly higher than those earned by the Nonmodeler group when both received the same treatment.

3. There were no significant differences in achievement between grade levels and no significant interaction effects found.

To determine whether Treatment 1 or Treatment 2 produced superior results post hoc comparisons of significance were made using the Scheffe test.

Table 14

Scheffe Tests for Treatment Comparisons With a 95 Per Cent Confidence Interval

Treatments	Confidence Interval	Result
(1 and 2) - 0	$2.214 \le \psi \le 3.746$	Significant
1 - 0	$1.698 \le \psi \le 3.468$	Significant
2 - 0	$2.491 \le \psi \le 4.259$	Significant
2 - 1	$-0.993 \le \psi \le 1.675$	Not significant

It was noted that both Treatments 1 and 2 produced results significantly higher than Treatment 0 but that Treatment 1 was not significantly superior to Treatment 2.

Types of Acceptable and Unacceptable Explanations

One of the advantages of the use of the clinical method in this study was the opportunity to observe the nature of the explanations given when the subjects did not use acceptable explanations.

It is noted from Tables 15 through 22 that: (1) the acceptable explanations included the use of nonanimistic nonmagical models, (2) most unacceptable explanations were nonanimistic and nonmagical, and (3) the unacceptable explanations varied. An analysis of these unacceptable responses revealed the usability of the following classification system.

Types of Unacceptable Explanations

I. Explanations are descriptions or restatements of the observations of the demonstrated phenomenon. (The water turned red.)

II. Effect is described utilizing common experiences and terminology which may or may not be science related. (Air inside might make the ball expand.)

III. Effect is described based upon logic derived from common experience apparently with the common concepts of conservation. (Alcohol was used up when they mixed.)

IV. Effect is described in terms of a dynamic impersonal force within the system. (Sugar is pushed around by the water.)

V. No explanation. (I don't know.)

Demonstration No. 1. It is revealed from Table 15 that in Grades 4, 5, and 6 there were ten different explanations given of which two were acceptable. Of the 46 subjects who gave acceptable explanations only one, a sixth-grade Nonmodeler, had not received either Treatment 1 or 2. It is also noted that both the Modelers-Treatment 1 or 2 and the Nonmodelers-Treatment 1 or 2 provided nearly equal numbers of acceptable explanations.

Although 26 subjects gave unacceptable explanations only three had received either Treatment 1 or 2. The nature of the unacceptable explanations includes all the identified types with the greatest number of subjects using Type II. Only seven of the subjects responded with "I don't know."

Demonstration No. 2. Note in Table 16 that each of the 72 subjects gave some type of explanation other than "I don't know" and that 57 of these were acceptable. One of the 48 subjects receiving Treatment 1 or 2 gave an unacceptable explanation whereas 14 of the 24 who received Treatment 0 gave unacceptable explanations. The unacceptable explanations given most frequently were of Type I.

Demonstration No. 3. From Table 17 it may be noted that 34 of the 36 subjects classified as Modelers and 21 of 36 Nonmodelers gave acceptable explanations. When subjects in the Treatment 1 and 2 groups are compared to those in the Treatment 0 groups, it is noted that 39 subjects or 81 per cent of the Treatment 1 and 2 groups gave acceptable explanations and 16 subjects or 66 per cent of the Treatment 0 group gave acceptable explanations.

The unacceptable explanations were predominantly of Type II with a few of Type IV. The subjects giving Type II explanations were Nonmodelers uniformly distributed among the three grade levels and those who gave Type IV explanations included two Modelers and two Nonmodelers, each of which included one Treatment 0 and one Treatment 1 or 2.

Table 15

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 1. Mixing of Alcohol and Water

	Grade 4				Grade 5				Grade 6			
Modeler - Nonmodeler	M		N		M		N		M		N	
Treatment	0	1-2	0	1-2	0	1-2	0	1-2	0	1-2	0	1-2
Acceptable explanations:												
1. Smaller water molecules fit in between the larger green molecules		3		5		6		6		4	1	5
2. Small water molecules take up some spaces between the alcohol molecules		5		1		2		2		3		3
Unacceptable explanations:												
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena												
3. Air went to the top	1		1									
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related												
4. The water evaporated			1	1					2			
5. They mix together and take up less room				1	2		1			1	1	
6. Got thick when mixed and went down	1											
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation												
7. Alcohol was used up when they mixed							2					
Type IV. Effect is described in terms of a dynamic impersonal force within the system												
8. Green stuff made the water heavier and it went down	1				1							
9. Alcohol above pushed the water together									1		1	
Type V. No explanation												
10. Don't know	1		2		1		1		1		1	

Demonstration No. 4. Examination of Table 18 reveals that 41 subjects or 57 per cent of the 72 subjects gave acceptable explanations and within this group there were 29 Modelers and 12 Nonmodelers. Some further observations are that the group giving acceptable explanations included 33 who had received Treatment 1 or 2; the 33 included 22 Modelers and 11 Nonmodelers; and there was only one Nonmodeler-Treatment 0 subject included.

There were 22 subjects who gave unacceptable explanations of Type IV and nine who gave "I don't know." The makeup of this group included 24 Nonmodelers about equally divided between Treatment 0 and Treatment 1 or 2 subjects and seven Modelers, two of whom received Treatment 1 or 2.

Demonstration No. 5. It is seen by referring to Table 19 that five explanations were given of which two were acceptable and that acceptable explanations were given by only 27 subjects or 37 per cent of the population tested. The group may be characterized in several ways: it includes 23 Modelers and four Nonmodelers; or it includes 21 Treatment 1 or 2 subjects and six Treatment 0 subjects; or it includes six Modeler-Treatment 0 subjects and the remaining 21 subjects had received Treatment 1 or 2.

The unacceptable explanations given by the remaining 45 subjects were predominantly of Type II with but a few of Types III and IV and no "I don't know" responses. The subjects came largely from the Nonmodeler groups; however, 20 received Treatment 1 or 2 and 12 received Treatment 0. The number of Modelers were nearly equally divided between Treatment 1 or 2 and Treatment 0.

Demonstration No. 6. Table 20 reveals that 15 Modeler subjects and one Nonmodeler subject gave acceptable explanations and that 14 of these subjects, including the one Nonmodeler, had received Treatment 1 or 2.

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Table 16

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 2. Expansion of Ball and Ring

	Grade 4				Grade 5				Grade 6			
Modeler - Nonmodeler	M		N		M		N		M		N	
Treatment	0	1-2	0	1-2	0	1-2	0	1-2	0	1-2	0	1-2
Acceptable explanations:												
1. Molecules move more when heated and take up more room		5		3		1		1	1	3		2
2. Molecules move faster when heated and take up more room		2		2		3		2	2	2		2
3. Molecules get bigger and push out when heated	3	1		1	3	3		4	1			1
4. Molecules move apart when heated				2		1		1		2		3
Unacceptable explanations:												
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena												
5. Ball and ring got bigger	1		4		1		3				3	
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related												
6. Air inside might expand											1	
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation												
Type IV. Effect is described in terms of a dynamic impersonal force within the system												
7. Molecules get stronger										1		
8. Ball and ring become magnetized when heated							1					
Type V. No explanation												

There were four unacceptable explanations, mainly of Type I, given by 45 subjects uniformly distributed among the grade levels and 11 who gave "I don't know" responses. This population came largely from the Nonmodeler groups and two-thirds of the subjects had received Treatment 1 or 2.

Demonstration No. 7. The three acceptable explanations listed in Table 21 were given by 37 subjects; 24 were Modelers and 13 were Nonmodelers. When the nature of the treatment is added to the Modeler-Nonmodeler classification it is obvious that the five subjects from the Treatment 0 groups were Modelers and that there were no Nonmodeler-Treatment 0 subjects included.

Unacceptable explanations, other than no explanation, were used by only four subjects, three being Type II and one Type IV.

Demonstration No. 8. The explanations supplied by the individual subjects who observed the sublimation of dry ice are noted in Table 22. The Modeler-Treatment 1 or 2 subjects provided 11 of the 14 acceptable explanations. Among the three remaining acceptable explanations two were supplied by Modeler-Treatment 0 subjects and one by a Nonmodeler-Treatment 1 or 2 subject.

The unacceptable explanations are equally distributed between Types I and II if the subject gave an unacceptable answer other than "I don't know."

Summary of Unacceptable Explanations

A consolidation of the types and frequencies of the unacceptable explanations provided, included in Table 23, indicates the degree of dependence placed upon common experience and probably the confusion between explanation and description.

Table 17

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 3. Dissolving of Sugar in Water

	Grade 4				Grade 5				Grade 6			
Modeler - Nonmodeler	M		N		M		N		M		N	
Treatment	0	1-2	0	1-2	0	1-2	0	1-2	0	1-2	0	1-2
Acceptable explanations:												
1. Sugar broke up into smaller pieces which are moving around with the water	3	1	1	2	2	1	1	1	1	1	2	
2. Water breaks up the sugar into smaller pieces that blend with the water	1	5		2	2	6	1	4	2	5		5
3. Sugar broke up into tiny molecules that are all over		2		1		1				1		1
Unacceptable explanations:												
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena												
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related												
4. Sugar evaporated			2								1	
5. It dissolved				3			2	2			1	1
6. Sugar took up spaces between the water molecules												1
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation												
Type IV. Effect is described in terms of a dynamic impersonal force within the system												
7. Sugar dissolves and is pushed around by the water			1					1		1		
8. Water squeezed the sugar so you couldn't see it									1			
Type V. No explanation												

It was possible to give 576 explanations if the 72 subjects each explained the eight phenomena. Within this possibility there were 283 or about 50 per cent unacceptable explanations. Within this the most common was Type II, that which depended upon common experience and terminology, followed by Type I which was mere description. The least common was the explanation that was "based upon logic derived from common experience apparently with common concepts of conservation."

Correlation of Test Score With Several Variables

In order to determine the degree of correlation between test score and age level, grade level of enrollment, IQ, mathematics concepts, mathematics computation, mathematics application, or science achievement a correlation matrix was obtained. The IQ was obtained from the Lorge-Thorndike IQ test and mathematics and science achievement scores from the Stanford Achievement Test. (See Appendix.) The degree of correlation of test score with each variable is noted in the top row of Table 24. The correlation coefficients for test score and grade level of enrollment and age are similar (.089 and .085), since subjects of like ages are normally in the same grade level. These low correlations coupled with the results obtained using analysis of variance technique indicate that scores on the demonstration test are not attributable to age or grade level.

The correlation coefficient of .258 between IQ and demonstration test score is in agreement with the findings of Deutsche (1937) who found little correlation between quantified test scores and IQ of 12-year-old subjects. This low correlation between IQ and test score is

Table 18

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 4. Expansion of Mercury in a Thermometer

	Grade 4				Grade 5				Grade 6			
Modeler - Nonmodeler	M		N		M		N		M		N	
Treatment	0	1-2	0	1-2	0	1-2	0	1-2	0	1-2	0	1-2
Acceptable explanations:												
1. When molecules get heated they get bigger and take up more room		2			1	1		1	1	3		2
2. The molecules went faster and took up more room		1		3		6		1	1	2		3
3. Heat made the molecules spread apart and take up more room	1	4			1			1	2	3	1	
Unacceptable explanations:												
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena												
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related												
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation												
Type IV. Effect is described in terms of a dynamic impersonal force within the system												
4. Heat pushed it up	3	1	2	3	2		4	2			3	2
Type V. No explanation			2	2		1		3				1

Table 19

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 5. Evaporation of Water

	Grade 4				Grade 5				Grade 6			
Modeler - Nonmodeler	M		N		M		N		M		N	
Treatment	0	1-2	0	1-2	0	1-2	0	1-2	0	1-2	0	1-2
Acceptable explanations:												
1. Molecules get so far apart that they go into the air		2		1	3	3				4		1
2. Molecules move so fast that they go out into the air		3		2		4			3	1		
Unacceptable explanations:												
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena												
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related												
3. It evaporated	3		4	3	1	1	4	8	1	3	3	7
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation												
4. The water breaks up into little bits		2										
Type IV. Effect is described in terms of a dynamic impersonal force within the system												
5. Water turned into air	1	1		2							1	
Type V. No explanation												

Table 20

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 6. Condensation of Water

	Grade 4				Grade 5				Grade 6			
Modeler - Nonmodeler	M		N		M		N		M		N	
Treatment	0	1-2	0	1-2	0	1-2	0	1-2	0	1-2	0	1-2
Acceptable explanations:												
1. The molecules slow down and get closer together when cooled	1	6				4			1	3		1
Unacceptable explanations:												
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena												
2. Water hits the pan		2	1	2		1		4	2	3	2	3
3. The pan traps water	3		2	2	2	1	2	2		1	2	3
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related												
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation												
Type IV. Effect is described in terms of a dynamic impersonal force within the system												
4. The molecules stuck to the pan				2	1							
5. Heat hit the pan					1	1						
Type V. No explanation												
6. I don't know			1	2		1	2	2	1	1		1

not to be expected since the subjects making up the Modeler group had IQ scores significantly higher than the Nonmodelers over all grade levels. (Table 26.)

The correlation coefficients for mathematics and science with the demonstration test scores were low in all instances with Mathematics Application (.314) being the highest.

THE SELECTION PROCESS; GRADES 2 AND 3

In the process of attempting to identify Modelers in the second and third grades, 35 subjects were interviewed without having identified any Modelers. Note in Table 27 that 19 subjects in third grade and 16 subjects in second grade were interviewed.

The random selection of eight subjects in each of Grades 2 and 3, to receive Treatments 1 and 2, from the Nonmodeler population previously isolated resulted in four boys and four girls being included from each grade. Since these were random selections no attempt was made to have equal members of both sexes. (Table 28)

THE TEST; GRADES 2 AND 3

Since each subject gave one explanation for each test demonstration it was possible to tabulate the responses to the eight demonstrations and to assign a score of 32 to the total test for each group of four subjects or a score of eight to a single subject if he gave acceptable explanations to the eight phenomena demonstrated.

A. Examination of Table 29 reveals the following:

1. The Nonmodelers in Grade 3 who received Treatment 1 had a total score of six. None of the subjects gave an acceptable explanation for phenomena beyond that included in Item 3, sugar and water. Two subjects each supplied two acceptable explanations and the other two subjects in the group each provided one.

2. The Nonmodelers in Grade 3 who received Treatment 2 had a total score of 17, which was 11 points higher than that for the Treatment 1 group. Only the phenomenon demonstrated in Item 6 was not given an acceptable explanation by any of the subjects in the group. There were four phenomena demonstrated for which three subjects supplied acceptable explanations and two supplied two acceptable explanations.

Table 21

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 7. Diffusion of Food Coloring in Water

	Grade 4				Grade 5				Grade 6			
Modeler - Nonmodeler	M		N		M		N		M		N	
Treatment	0	1-2	0	1-2	0	1-2	0	1-2	0	1-2	0	1-2
Acceptable explanations:												
1. The warm water molecules are moving the food coloring molecules	2	3		4		4		2	3	2		4
2. The heat causes the molecules to move around faster		2		1				1		3		
3. Molecules are always moving so we can see the food coloring moving		1				2				2		1
Unacceptable explanations:												
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena												
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related												
4. Food coloring molecules are thicker than water molecules				1								
5. The food coloring is like the alcohol and water							1				1	
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation												
Type IV. Effect is described in terms of a dynamic impersonal force within the system												
6. Gravity m.. ':es the water move											1	
Type V. No explanation												
7. I don't know	2	2	4	2	4	2	3	5	1	1	2	3

The achievement of the individual subjects ranged from one acceptable explanation to seven acceptable explanations.

3. The Nonmodeler group in Grade 2 that received Treatment 1 earned a score of eight. The acceptable explanations were all given for the first three phenomena demonstrated as was also noted for the third grade Nonmodeler-Treatment 1 group. There were three acceptable explanations used for two of the phenomena demonstrated and two acceptable explanations for the third.

The achievement of the individual subjects was consistent as they all had a score of two.

4. The Nonmodelers in Grade 2 who received Treatment 2 had a total score of 12 which was only four points higher than the Nonmodeler-Treatment 1 group. Acceptable explanations were provided for five of the eight test items. Test Item 2, Ball and Ring, was acceptably explained by all four subjects in the group.

One of the subjects acceptably explained five of the eight phenomena demonstrated while another subject gave acceptable explanations for four. Both of these subjects acceptably explained their observation of the first four phenomena demonstrated.

It is noted from further examination of Table 29 that in the second grade only one acceptable explanation was provided for the phenomena demonstrated in Items 5 to 8, while in the third grade six acceptable explanations were given for the phenomena demonstrated in Items 5 to 8.

5. Summary. The scores earned by the subjects at the second- and third-grade levels indicate that:

a. Subjects at this level who do not use acceptable models can be taught to use such models to explain physical phenomena involving the particle theory of matter.

b. Subjects in Grade 3 did not earn significantly higher scores on the test than

Table 22

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 8. Sublimation of Dry Ice

	Grade 4				Grade 5				Grade 6			
Modeler - Nonmodeler	M		N		M		N		M		N	
Treatment	0	1-2	0	1-2	0	1-2	0	1-2	0	1-2	0	1-2
Acceptable explanations:												
1. It evaporates by little pieces going directly into the air		2										
2. The pan warmed the molecules and they went so fast that they went right into the air		1		1		4			2	4		
Unacceptable explanations:												
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena												
3. It disappeared	2	5	1	3		1	1	3	2	1	1	3
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related												
4. It evaporates	1		3	1	4	2	3	2		3	2	2
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation												
Type IV. Effect is described in terms of a dynamic impersonal force within the system												
Type V. No explanation												
5. I don't know	1			3		1		3			1	3

Table 23

Number of Subjects and Classification of the Unacceptable Explanations For Each Phenomenon Demonstrated in the Model Usage Test

Type of Explanation	Test Demonstrations								
	1	2	3	4	5	6	7	8	Total
I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena	2	12	0	0	0	40	0	23	77
II. Effect is described utilizing common experiences and terminology which may or may not be science related	11	1	13	0	38	0	3	23	89
III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation	2	0	0	0	2	0	0	0	4
IV. Effect is described in terms of a dynamic impersonal force within the system	4	2	4	22	5	5	1	0	43
V. No explanation	7	0	0	9	0	11	31	12	70

Table 24

Correlation Matrix of the Model Usage Test Scores With Grade Level, Age, IQ, Mathematics Achievement, and Science Achievement

	Test Score	Grade Level	Age	IQ	Mathematics Concepts	Mathematics Computation	Mathematics Application	Science Achievement
Test Score	1.000	0.089	0.085	0.258	0.265	0.020	0.314	0.204
Grade Level		1.000	0.873	0.147	0.261	0.014	0.044	0.013
Age			1.000	0.062	0.226	0.036	0.057	-.014
IQ				1.000	0.672	0.571	0.692	0.784
Mathematics Concepts					1.000	0.505	0.727	0.661
Mathematics Computation						1.000	0.533	0.471
Mathematics Application							1.000	0.673
Science Achievement								1.000

Table 25

IQ of Subjects in Investigation Presented As Modeler and Nonmodeler Groups and By Grade Level

Grade	Mean IQ	
	Modeler	Nonmodeler
4	109.75	99.58
5	113.91	100.91
6	112.08	105.33
Total	111.91	101.94

Table 26

Comparison of Modeler and Nonmodeler Mean IQ Utilizing the t-Test

Difference Between Modeler and Nonmodeler IQ	Observed Value of t	Critical Value of t
9.97	3.65	1.99

$\alpha = .05$

Table 27

Number of Subjects in Grades 2 and 3 Tested in the Process of Selecting Modelers

Grade	Children Interviewed	Modelers	Non-modelers
3	19	0	19
2	16	0	16
Total	35	0	35

Table 28

Distribution of Nonmodeler Population Selected For Treatments By Grade and Sex

Grade	Boys	Girls
3	4	4
2	4	4
Total	8	8

subjects in Grade 2 when both groups had received appropriate instruction.

c. An analogous dynamic mechanical model is not superior to an analogous static mechanical model in teaching subjects at the levels of Grades 2 and 3 to use acceptable models to explain physical phenomena involving the particle theory of matter.

Table 29

Posttest Results For Grades 2 and 3 Arranged By Group, Treatment, and Demonstration

Grade	Non-Modeler	Treat-ment	Score	Demonstration 1	2	3	4	5	6	7	8
3	N	2	5	x	x	x	x			x	
3	N	2	1	x							
3	N	2	7	x	x	x	x	x		x	x
3	N	2	4		x	x		x		x	
3	N	1	2	x		x					
3	N	1	2	x	x						
3	N	1	1			x					
3	N	1	1		x						
2	N	2	1		x						
2	N	2	2		x	x					
2	N	2	4	x	x	x	x				
2	N	2	5	x	x	x	x			x	
2	N	1	2		x	x					
2	N	1	2	x	x						
2	N	1	2	x		x					
2	N	1	2	x	x						

ANALYSIS OF DATA; GRADES 2 AND 3

The mean scores for each of the two cells in Grades 2 and 3 are noted in Table 30.

A two-sample t-test was used to compare the scores of those Nonmodeler subjects receiving Treatment 1 with those receiving Treatment 2 in each grade.

The Treatment effects for Grades 2 and 3 were not significantly different and thus cannot be attributed to the treatment. There was no way to arrive at the effect of Modelers as compared to Nonmodelers since there were no Modelers in Grades 2 and 3. Since there were Nonmodeler-Treatment 1 and Treatment 2 subjects in all Grades 2-6, a one-way analysis of variance of these test scores was used to determine the grade-level effect.

The analysis of variance indicated that at the .05 level of significance there was no significant difference in test scores attributable to grade-level effect for Grades 2 through 6.

Types of Explanations Used for Test Demonstrations in Grades 2 and 3

Each of the 16 subjects, eight in each of Grades 2 and 3, presented one explanation for each of the eight phenomena demonstrated in the Model Usage test. These explanations have been grouped as discussed previously and are presented in Tables 33 to 40.

Table 30

Mean Scores Arranged According to Grade Level and Treatment

Grade	Treatment 1	Treatment 2
3	1.5	4.25
2	2.0	3.00

Table 31

Comparison of Mean Scores By Treatment Groups Using the t-Test With Alpha .05

Means Being Compared	Calculated t value	Critical t value
2-N-1 vs. 2-N-2	.952	2.447
3-N-1 vs. 3-N-2	1.856	2.447

Table 32

Summary Table for the Analysis of Variance of Grade Level Effect of All Nonmodeler Groups Receiving Treatment 1 or 2 in Grades 2 Through 6

Source	SS	df	MS	F	F (critical)
Grade level effect (between groups)	16.3	4	4.025	1.87	2.65
Error (within groups)	75.1	35	2.145		
Total	91.4	39		$\alpha = .05$	

Demonstration No. 1. Table 33 reveals that ten subjects provided three acceptable explanations and that there was no difference between Grades 2 and 3. Of the five subjects providing acceptable explanations in Grade 2, three received Treatment 1 and two Treatment 2; however, in Grade 3 the reverse was found.

The unacceptable explanations given by six subjects were of Types I and IV in addition to "I don't know," and the most common were Type I.

Demonstration No. 2. The list of explanations given in Table 34 includes five that were acceptable and given by one or more of the 12 subjects. Again the subjects were about equally distributed by grade level. Treatment effects were distributed 5:7 with five subjects receiving Treatment 1 and seven receiving Treatment 2.

The only unacceptable type of explanation was a Type I given by one second-grade subject and three third-grade subjects. Treatment effects do not seem apparent.

Demonstration No. 3. The uniform distribution of acceptable explanations is again noted in Table 35 which reveals that five Grade 2 subjects, two Treatment 1 and three Treatment 2; and five Grade 3 subjects, two Treatment 1 and three Treatment 2 gave acceptable explanations.

The unacceptable explanations given by six subjects included one Type II and one Type IV in addition to "I don't know." The nature of the treatment appears to have no effect in this instance.

Demonstration No. 4. It is noted in Table 36 that the number of subjects giving acceptable explanations has decreased to four; two subjects in each grade, both of whom received Treatment 2.

Unacceptable explanations were supplied by 12 subjects and the largest number were of Type IV, given by nine subjects.

Demonstration No. 5. The acceptable explanation given by only two subjects in the Grade 3-Treatment 2 group is included in Table 37. The list also includes the four unacceptable types of explanations given by one or more of 14 subjects equally distributed in Grades 2 and 3. Type II explanations were most commonly given by this group. Identification of effects attributable to treatment does not seem possible because of the distribution of scores.

Demonstration No. 6. Examination of Table 38 reveals that no acceptable explanations were provided for the phenomenon demonstrated in this test item. Type IV explanations were given by nine subjects and Type II were given by six subjects distributed equally in the two grades and between the two treatments.

Demonstration No. 7. The explanations given in Table 39 include one that was acceptable given by four subjects, three of whom were in the Grade 3-Treatment 2 group. The 12 subjects who gave unacceptable explanations other than "I don't know" gave those predominantly of Type I regardless of the treatment or grade level.

Table 33

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 1. Mixing of Alcohol and Water

Treatment	Grade 2 Nonmodeler 1	Grade 2 Nonmodeler 2	Grade 3 Nonmodeler 1	Grade 3 Nonmodeler 2
Acceptable explanations:				
1. The little water particles squeezed in between the larger alcohol particles	2	1		1
2. The little and big ones mixed so that little ones went in between larger ones	1		1	
3. The smaller water molecules fit in between the larger alcohol molecules		1	1	2
Unacceptable explanations:				
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena				
4. Went down when alcohol and water mixed	1	1	1	
5. It takes less room		1		
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related				
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation				
Type IV. Effect is described in terms of a dynamic impersonal force within the system				
6. Green stuff is stronger			1	
Type V. No explanation				
7. I don't know				1

Demonstration No. 8. It is noted in Table 40 that only one explanation, that given by a Grade 3-Treatment 2 subject, was acceptable. A majority of the unacceptable explanations given were of Type I and the minority were of Type II regardless of grade and treatment.

Summary of Unacceptable Explanations in Grades 2 and 3

Consolidating the types and frequencies of unacceptable explanations given by subjects in Grades 2 and 3 as noted in Table 41 reveals that of a possible 128 explanations 85, or 66 per cent, were unacceptable. As in Grades 4, 5, and 6 there appears to be high degree of dependence upon common experience and perhaps a confusion between explanation and description. Three types of explanations included 90 per cent of the unacceptable explanations given, the most frequently used being Type I, description of observation, followed equally by Type II, common experience, and Type IV, utilizing a dynamic force within the system. Type III explanations which were infrequently used in Grades 4, 5, and 6 were completely absent in Grades 2 and 3.

Table 34

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 2. Expansion of Ball and Ring

	Grade 2		Grade 3	
	Nonmodeler		Nonmodeler	
Treatment	1	2	1	2
Acceptable explanations:				
1. The little round things moved apart when heated so the ring got bigger	2			
2. The particles in the ring spread apart when heated	1	2	1	
3. The molecules in the ring moved faster and took up more room		2		
4. The molecules grew bigger and made the ring bigger			1	
5. The molecules were moving faster when heated				3
Unacceptable explanations:				
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena				
6. The ring got bigger	1		2	1
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related				
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation				
Type IV. Effect is described in terms of a dynamic impersonal force within the system				
Type V. No explanation				

Table 35

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 3. Dissolving of Sugar in Water

	Grade 2		Grade 3	
	Nonmodeler		Nonmodeler	
Treatment	1	2	1	2
Acceptable explanations:				
1. Sugar broke into little pieces that were all over	2	2	1	2
2. The sugar breaks up into small molecules		1		
3. The sugar falls apart into smaller pieces that you can't see			1	1
Unacceptable explanations:				
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena				
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related				
4. It dissolved	1			
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation				
Type IV. Effect is described in terms of a dynamic impersonal force within the system				
5. The sugar went out the top (evaporated)			1	
Type V. No explanation				
6. I don't know	1	1	1	1

Table 36

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 4. Expansion of Mercury in a Thermometer

	Grade 2		Grade 3	
	Nonmodeler		Nonmodeler	
Treatment	1	2	1	2
Acceptable explanations:				
1. The molecules moved more when heated and took up more room		2		2
Unacceptable explanations:				
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena				
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related				
2. Goes up in heat and down in cold	1			
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation				
Type IV. Effect is described in terms of a dynamic impersonal force within the system				
3. Heat made it go up	1	2	4	2
Type V. No explanation				
4. I don't know	2			

Table 37

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 5. Evaporation of Water

Treatment	Grade 2 Nonmodeler 1	Grade 2 Nonmodeler 2	Grade 3 Nonmodeler 1	Grade 3 Nonmodeler 2
Acceptable explanations:				
1. The molecules moved so fast when heated that they went right into the air				2
Unacceptable explanations:				
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena				
2. The water went away	1	1		
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related				
3. The water went up into the air	2	1		
4. The molecules got hot and melted		1		
5. The water evaporates		1	3	2
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation				
Type IV. Effect is described in terms of a dynamic impersonal force within the system				
6. Heat makes it dry up	1		1	
Type V. No explanation				

Table 38

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 6. Condensation of Water

Treatment	Grade 2 Nonmodeler 1	Grade 2 Nonmodeler 2	Grade 3 Nonmodeler 1	Grade 3 Nonmodeler 2
Acceptable explanations:				
Unacceptable explanations:				
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena				
1. There was water on the pan	1			
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related				
2. The steam makes it get wet	1	2	2	
3. The air evaporated				1
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation				
Type IV. Effect is described in terms of a dynamic impersonal force within the system				
4. Air pushed the water up	1	1		
5. Heat made the water go up	1	1	1	3
6. Pressure pushes the water up			1	
Type V. No explanation				

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Table 39

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 7. Diffusion of Food Coloring in Water

	Grade 2		Grade 3	
	Nonmodeler		Nonmodeler	
Treatment	1	2	1	2
Acceptable explanations:				
1. The hot water molecules made the colored molecules move more		1		3
Unacceptable explanations:				
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena				
2. It moves around	2		1	
3. The red stuff moves around	1	2		1
4. The water shakes and it all moves	1	1	1	
5. The water gets red			1	
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related				
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation				
Type IV. Effect is described in terms of a dynamic impersonal force within the system				
6. Air pushes the food coloring			1	
Type V. No explanation				

Table 40

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 8. Sublimation of Dry Ice

	Grade 2		Grade 3	
	Nonmodeler		Nonmodeler	
Treatment	1	2	1	2
Acceptable explanations:				
1. The molecules get warm from the pan and move right into the air				1
Unacceptable explanations:				
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena				
2. It disappears	3	1	2	2
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related				
3. It melted	1	3	1	
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation				
Type IV. Effect is described in terms of a dynamic impersonal force within the system				
Type V. No explanation				
4. I don't know			1	1

Table 41

Number of Subjects and Classification of the Unacceptable Explanations For Each Pehnomenon Demonstrated in the Model Usage Test

Type of Explanation	Test Demonstrations								
	1	2	3	4	5	6	7	8	Total
I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena	4	4	0	0	2	1	11	8	30
II. Effect is described utilizing common experiences and terminology which may or may not be science related	0	0	1	1	10	6	0	5	23
III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation	0	0	0	0	0	0	0	0	0
IV. Effect is described in terms of a dynamic impersonal force within the system	1	0	1	9	2	9	1	0	23
V. No explanation	1	0	4	2	0	0	0	2	9

V
CONCLUSIONS

CONCLUSIONS

1. The variety of stimuli to which children in Grades 4-6 respond and from which they acquire their educational backgrounds commonly includes opportunities to explain physical phenomena using acceptable models as the particle theory of matter.

2. The variety of stimuli to which children in Grades 2-3 respond and from which they acquire their educational backgrounds does not commonly include opportunities appropriate to their learning to use acceptable models as the particle theory of matter in explaining physical phenomena.

3. The proportional number of children who learn to use acceptable models in explaining physical phenomena as a result of the programs commonly determining their educational backgrounds seems to be increasingly appropriate with each increase in grade level from 3 to 6.

4. Children in Grades 2-6 who had not learned to use the particle theory of matter to explain natural physical phenomena within present educational programs can learn to use this theoretical model as a result of appropriate instruction.

5. Children in Grades 4 and 5 who already make some use of acceptable models, as the particle theory of the nature of matter in explaining physical phenomena, improve in this ability as a result of appropriate instruction.

6. Children in Grades 4-6 who made some use of acceptable models prior to a period of appropriate instruction attain a significantly higher level of achievement, as indicated by test scores, than do children from the same grade levels who do not use acceptable models prior to instruction when both groups receive the same appropriate instruction.

7. Within the limits of this study, grade level is not a factor of concern in teaching the use of the particle model of matter in explaining physical phenomena.

8. Within the limits of this study and the limits of the tests used to determine IQ and level of achievement in science and mathematics, the factors of IQ and achievement in science and mathematics are not factors that determine whether or not the use of the model the particle theory of matter should be taught in Grades 2-6.

9. Children in Grades 2-6 who did not use acceptable models to explain physical phenomena most often used "common everyday experiences and terminology which may or may not be science related" or gave "descriptions of observations."

10. The dynamic mechanical model, though usually numerically superior, was not significantly superior to the static mechanical model as an instructional aid in teaching the use of the model the particle theory of matter in explaining physical phenomena to children in Grades 2-6.

11. Children in Grades 2-6 do not make extensive use of magical or animistic models in explaining physical phenomena. This is in agreement with Huang, Oakes, and others.

12. Children can be taught to use the particle theory of matter at the descriptive or classification level to explain expansion and contraction, change of phase including sublimation, diffusion, and mixtures by the time they complete Grade 4.

IMPLICATIONS

1. Children can be taught to use acceptable theoretical models if the instruction provided is appropriate. The term appropriate here would include the use of mechanical models of either the static or dynamic varieties.

2. Since the level of achievement of Modelers consistently exceeds that of Nonmodelers there appears to be a factor of time for acceptance or assimilation of this abstract idea. Children should thus be exposed to ideas of this type so they can make maximum progress throughout the educational program.

3. Children in Grades 2-6 with wide ranges of IQ's and varying levels of achievement in science and mathematics may be taught to use theoretical concepts in explaining physical phenomena when in the instructional procedure appropriate mechanical models are used.

4. It seems that the use of analogous models in teaching theoretical concepts serves to move the concept from the logical operations stage to the concrete operations stage for the child. This observation is supported by the lack of significance of IQ, grade level, age, and past achievement in science and mathematics to the learning that took place during this study.

5. Science curriculum programs for the elementary school may consider that children in Grades 2-6 can form theoretical concepts if provided with concrete experience analogies as a part of an otherwise appropriate program.

Table 22

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 8. Sublimation of Dry Ice

	Grade 4				Grade 5				Grade 6			
Modeler - Nonmodeler	M		N		M		N		M		N	
Treatment	0	1-2	0	1-2	0	1-2	0	1-2	0	1-2	0	1-2
ceptable explanations:												
1. It evaporates by little pieces going directly into the air		2										
2. The pan warmed the molecules and they went so fast that they went right into the air		1		1		4			2	4		
acceptable explanations:												
ype I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena												
3. It disappeared	2	5	1	3		1	1	3	2	1	1	3
ype II. Effect is described utilizing common experiences and terminology which may or may not be science related												
4. It evaporates	1		3	1	4	2	3	2		3	2	2
ype III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation												
ype IV. Effect is described in terms of a dynamic impersonal force within the system												
ype V. No explanation												
5. I don't know	1			3		1		3			1	3

Table 23

Number of Subjects and Classification of the Unacceptable Explanations For Each Phenomenon Demonstrated in the Model Usage Test

Type of Explanation	Test Demonstrations								
	1	2	3	4	5	6	7	8	Total
. Explanations are descriptions or restatements of the observations of the demonstrated phenomena	2	12	0	0	0	40	0	23	77
. Effect is described utilizing common experiences and terminology which may or may not be science related	11	1	13	0	38	0	3	23	89
. Effect is described based upon logic derived from common experience apparently with common concepts of conservation	2	0	0	0	2	0	[illegible]	0	4
. Effect is described in terms of a dynamic impersonal force within the system	4	2	4	22	5	5	1	0	43
. No explanation	7	0	0	9	0	11	31	12	70

Table 24

Correlation Matrix of the Model Usage Test Scores With Grade Level, Age, IQ, Mathematics Achievement, and Science Achievement

	Test Score	Grade Level	Age	IQ	Mathematics Concepts	Mathematics Computation	Mathematics Application	Science Achievement
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Difference Between Modeler and Nonmodeler IQ	Observed Value of t	Critical Value of t
9.97	3.65	1.99

$\alpha = .05$

subjects in Grade 2 when both groups had received appropriate instruction.

c. An analogous dynamic mechanical model is not superior to an analogous static mechanical model in teaching subjects at the levels of Grades 2 and 3 to use acceptable models to explain physical phenomena involving the particle theory of matter.

Table 27

Number of Subjects in Grades 2 and 3 Tested in the Process of Selecting Modelers

Grade	Children Interviewed	Modelers	Nonmodelers
3	19	0	19
2	16	0	16
Total	35	0	35

Table 28

Distribution of Nonmodeler Population Selected For Treatments By Grade and Sex

Grade	Boys	Girls
3	4	4
2	4	4
Total	8	8

Table 29

Posttest Results For Grades 2 and 3 Arranged By Group, Treatment, and Demonstration

Grade	Non-Modeler	Treat-ment	Score	Demonstration							
				1	2	3	4	5	6	7	8
3	N	2	5	x	x	x	x			x	
3	N	2	1	x							
3	N	2	7	x	x	x	x	x		x	x
3	N	2	4		x	x		x		x	
3	N	1	2	x		x					
3	N	1	2	x	x						
3	N	1	1			x					
3	N	1	1		x						
2	N	2	1		x						
2	N	2	2		x	x					
2	N	2	4	x	x	x	x				
2	N	2	5	x	x	x	x			x	
2	N	1	2		x	x					
2	N	1	2	x	x						
2	N	1	2	x		x					
2	N	1	2	x	x						

ANALYSIS OF DATA; GRADES 2 AND 3

The mean scores for each of the two cells in Grades 2 and 3 are noted in Table 30.

A two-sample t-test was used to compare the scores of those Nonmodeler subjects receiving Treatment 1 with those receiving Treatment 2 in each grade.

The Treatment effects for Grades 2 and 3 were not significantly different and thus cannot be attributed to the treatment. There was no way to arrive at the effect of Modelers as compared to Nonmodelers since there were no Modelers in Grades 2 and 3. Since there were Nonmodeler-Treatment 1 and Treatment 2 subjects in all Grades 2-6, a one-way analysis of variance of these test scores was used to determine the grade-level effect.

The analysis of variance indicated that at the .05 level of significance there was no significant difference in test scores attributable to grade-level effect for Grades 2 through 6.

Types of Explanations Used for Test Demonstrations in Grades 2 and 3

Each of the 16 subjects, eight in each of Grades 2 and 3, presented one explanation for each of the eight phenomena demonstrated in the Model Usage test. These explanations have been grouped as discussed previously and are presented in Tables 33 to 40.

Table 30

Mean Scores Arranged According to Grade Level and Treatment

Grade	Treatment 1	Treatment 2
3	1.5	4.25
2	2.0	3.00

Table 31

Comparison of Mean Scores By Treatment Groups Using the t-Test With Alpha .05

Means Being Compared	Calculated t value	Critical t value
2-N-1 vs. 2-N-2	.952	2.447
3-N-1 vs. 3-N-2	1.856	2.447

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Table 32

Summary Table for the Analysis of Variance of Grade Level Effect of All Nonmodeler Groups Receiving Treatment 1 or 2 in Grades 2 Through 6

Source	SS	df	MS	F	F (critical)
Grade level effect (between groups)	16.3	4	4.025	1.87	2.65
Error (within groups)	75.1	35	2.145		
Total	91.4	39		$\alpha = .05$	

Demonstration No. 1. Table 33 reveals that ten subjects provided three acceptable explanations and that there was no difference between Grades 2 and 3. Of the five subjects providing acceptable explanations in Grade 2, three received Treatment 1 and two Treatment 2; however, in Grade 3 the reverse was found.

The unacceptable explanations given by six subjects were of Types I and IV in addition to "I don't know," and the most common were Type I.

Demonstration No. 2. The list of explanations given in Table 34 includes five that were acceptable and given by one or more of the 12 subjects. Again the subjects were about equally distributed by grade level. Treatment effects were distributed 5:7 with five subjects receiving Treatment 1 and seven receiving Treatment 2.

The only unacceptable type of explanation was a Type I given by one second-grade subject and three third-grade subjects. Treatment effects do not seem apparent.

Demonstration No. 3. The uniform distribution of acceptable explanations is again noted in Table 35 which reveals that five Grade 2 subjects, two Treatment 1 and three Treatment 2; and five Grade 3 subjects, two Treatment 1 and three Treatment 2 gave acceptable explanations.

The unacceptable explanations given by six subjects included one Type II and one Type IV in addition to "I don't know." The nature of the treatment appears to have no effect in this instance.

Demonstration No. 4. It is noted in Table 36 that the number of subjects giving acceptable explanations has decreased to four; two subjects in each grade, both of whom received Treatment 2.

Unacceptable explanations were supplied by 12 subjects and the largest number were of Type IV, given by nine subjects.

Demonstration No. 5. The acceptable explanation given by only two subjects in the Grade 3-Treatment 2 group is included in Table 37. The list also includes the four unacceptable types of explanations given by one or more of 14 subjects equally distributed in Grades 2 and 3. Type II explanations were most commonly given by this group. Identification of effects attributable to treatment does not seem possible because of the distribution of scores.

Demonstration No. 6. Examination of Table 38 reveals that no acceptable explanations were provided for the phenomenon demonstrated in this test item. Type IV explanations were given by nine subjects and Type II were given by six subjects distributed equally in the two grades and between the two treatments.

Demonstration No. 7. The explanations given in Table 39 include one that was acceptable given by four subjects, three of whom were in the Grade 3-Treatment 2 group. The 12 subjects who gave unacceptable explanations other than "I don't know" gave those predominantly of Type I regardless of the treatment or grade level.

Table 33

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 1. Mixing of Alcohol and Water

	Grade 2 Nonmodeler		Grade 3 Nonmodeler	
Treatment	1	2	1	2
Acceptable explanations:				
1. The little water particles squeezed in between the larger alcohol particles	2	1		1
2. The little and big ones mixed so that little ones went in between larger ones	1		1	
3. The smaller water molecules fit in between the larger alcohol molecules		1	1	2
Unacceptable explanations:				
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena				
4. Went down when alcohol and water mixed	1	1	1	
5. It takes less room		1		
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related				
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation				
Type IV. Effect is described in terms of a dynamic impersonal force within the system				
6. Green stuff is stronger			1	
Type V. No explanation				
7. I don't know				1

Demonstration No. 8. It is noted in Table 40 that only one explanation, that given by a Grade 3-Treatment 2 subject, was acceptable. A majority of the unacceptable explanations given were of Type I and the minority were of Type II regardless of grade and treatment.

Summary of Unacceptable Explanations in Grades 2 and 3

Consolidating the types and frequencies of unacceptable explanations given by subjects in Grades 2 and 3 as noted in Table 41 reveals that of a possible 128 explanations 85, or 66 per cent, were unacceptable. As in Grades 4, 5, and 6 there appears to be high degree of dependence upon common experience and perhaps a confusion between explanation and description. Three types of explanations included 90 per cent of the unacceptable explanations given, the most frequently used being Type I, description of observation, followed equally by Type II, common experience, and Type IV, utilizing a dynamic force within the system. Type III explanations which were infrequently used in Grades 4, 5, and 6 were completely absent in Grades 2 and 3.

Table 34

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 2. Expansion of Ball and Ring

	Grade 2		Grade 3	
	Nonmodeler		Nonmodeler	
Treatment	1	2	1	2
Acceptable explanations:				
1. The little round things moved apart when heated so the ring got bigger	2			
2. The particles in the ring spread apart when heated	1	2	1	
3. The molecules in the ring moved faster and took up more room		2		
4. The molecules grew bigger and made the ring bigger			1	
5. The molecules were moving faster when heated				3
Unacceptable explanations:				
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena				
6. The ring got bigger	1		2	1
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related				
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation				
Type IV. Effect is described in terms of a dynamic impersonal force within the system				
Type V. No explanation				

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Table 35

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 3. Dissolving of Sugar in Water

	Grade 2		Grade 3	
	Nonmodeler		Nonmodeler	
Treatment	1	2	1	2
Acceptable explanations:				
1. Sugar broke into little pieces that were all over	2	2	1	2
2. The sugar breaks up into small molecules		1		
3. The sugar falls apart into smaller pieces that you can't see			1	1
Unacceptable explanations:				
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena				
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related				
4. It dissolved	1			
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation				
Type IV. Effect is described in terms of a dynamic impersonal force within the system				
5. The sugar went out the top (evaporated)			1	
Type V. No explanation				
6. I don't know	1	1	1	1

Table 36

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 4. Expansion of Mercury in a Thermometer

	Grade 2		Grade 3	
	Nonmodeler		Nonmodeler	
Treatment	1	2	1	2
Acceptable explanations:				
1. The molecules moved more when heated and took up more room		2		2
Unacceptable explanations:				
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena				
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related				
2. Goes up in heat and down in cold	1			
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation				
Type IV. Effect is described in terms of a dynamic impersonal force within the system				
3. Heat made it go up	1	2	4	2
Type V. No explanation				
4. I don't know	2			

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Table 37

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 5. Evaporation of Water

	Grade 2		Grade 3	
	Nonmodeler		Nonmodeler	
Treatment	1	2	1	2
Acceptable explanations:				
1. The molecules moved so fast when heated that they went right into the air				2
Unacceptable explanations:				
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena				
2. The water went away	1	1		
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related				
3. The water went up into the air	2	1		
4. The molecules got hot and melted		1		
5. The water evaporates		1	3	2
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation				
Type IV. Effect is described in terms of a dynamic impersonal force within the system				
6. Heat makes it dry up	1		1	
Type V. No explanation				

Table 38

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 6. Condensation of Water

	Grade 2		Grade 3	
	Nonmodeler		Nonmodeler	
Treatment	1	2	1	2
Acceptable explanations:				
Unacceptable explanations:				
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena				
1. There was water on the pan	1			
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related				
2. The steam makes it get wet	1	2	2	
3. The air evaporated				1
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation				
Type IV. Effect is described in terms of a dynamic impersonal force within the system				
4. Air pushed the water up	1	1		
5. Heat made the water go up	1	1	1	3
6. Pressure pushes the water up			1	
Type V. No explanation				

Table 39

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 7. Diffusion of Food Coloring in Water

	Grade 2 Nonmodeler		Grade 3 Nonmodeler	
Treatment	1	2	1	2
Acceptable explanations:				
1. The hot water molecules made the colored molecules move more		1		3
Unacceptable explanations:				
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena				
2. It moves around	2		1	
3. The red stuff moves around	1	2		1
4. The water shakes and it all moves	1	1	1	
5. The water gets red			1	
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related				
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation				
Type IV. Effect is described in terms of a dynamic impersonal force within the system				
6. Air pushes the food coloring			1	
Type V. No explanation				

Table 40

Nature and Frequency of Explanations Given for the Phenomenon in Demonstration 8. Sublimation of Dry Ice

	Grade 2 Nonmodeler		Grade 3 Nonmodeler	
Treatment	1	2	1	2
Acceptable explanations:				
1. The molecules get warm from the pan and move right into the air				1
Unacceptable explanations:				
Type I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena				
2. It disappears	3	1	2	2
Type II. Effect is described utilizing common experiences and terminology which may or may not be science related				
3. It melted	1	3	1	
Type III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation				
Type IV. Effect is described in terms of a dynamic impersonal force within the system				
Type V. No explanation				
4. I don't know			1	1

Table 41

Number of Subjects and Classification of the Unacceptable Explanations For Each Pehnomenon Demonstrated in the Model Usage Test

Type of Explanation	Test Demonstrations								
	1	2	3	4	5	6	7	8	Total
I. Explanations are descriptions or restatements of the observations of the demonstrated phenomena	4	4	0	0	2	1	11	8	30
II. Effect is described utilizing common experiences and terminology which may or may not be science related	0	0	1	1	10	6	0	5	23
III. Effect is described based upon logic derived from common experience apparently with common concepts of conservation	0	0	0	0	0	0	0	0	0
IV. Effect is described in terms of a dynamic impersonal force within the system	1	0	1	9	2	9	1	0	23
V. No explanation	1	0	4	2	0	0	0	2	9

V
CONCLUSIONS

CONCLUSIONS

1. The variety of stimuli to which children in Grades 4-6 respond and from which they acquire their educational backgrounds commonly includes opportunities to explain physical phenomena using acceptable models as the particle theory of matter.

2. The variety of stimuli to which children in Grades 2-3 respond and from which they acquire their educational backgrounds does not commonly include opportunities appropriate to their learning to use acceptable models as the particle theory of matter in explaining physical phenomena.

3. The proportional number of children who learn to use acceptable models in explaining physical phenomena as a result of the programs commonly determining their educational backgrounds seems to be increasingly appropriate with each increase in grade level from 3 to 6.

4. Children in Grades 2-6 who had not learned to use the particle theory of matter to explain natural physical phenomena within present educational programs can learn to use this theoretical model as a result of appropriate instruction.

5. Children in Grades 4 and 5 who already make some use of acceptable models, as the particle theory of the nature of matter in explaining physical phenomena, improve in this ability as a result of appropriate instruction.

6. Children in Grades 4-6 who made some use of acceptable models prior to a period of appropriate instruction attain a significantly higher level of achievement, as indicated by test scores, than do children from the same grade levels who do not use acceptable models prior to instruction when both groups receive the same appropriate instruction.

7. Within the limits of this study, grade level is not a factor of concern in teaching the use of the particle model of matter in explaining physical phenomena.

8. Within the limits of this study and the limits of the tests used to determine IQ and level of achievement in science and mathematics, the factors of IQ and achievement in science and mathematics are not factors that determine whether or not the use of the model the particle theory of matter should be taught in Grades 2-6.

9. Children in Grades 2-6 who did not use acceptable models to explain physical phenomena most often used "common everyday experiences and terminology which may or may not be science related" or gave "descriptions of observations."

10. The dynamic mechanical model, though usually numerically superior, was not significantly superior to the static mechanical model as an instructional aid in teaching the use of the model the particle theory of matter in explaining physical phenomena to children in Grades 2-6.

11. Children in Grades 2-6 do not make extensive use of magical or animistic models in explaining physical phenomena. This is in agreement with Huang, Oakes, and others.

12. Children can be taught to use the particle theory of matter at the descriptive or classification level to explain expansion and contraction, change of phase including sublimation, diffusion, and mixtures by the time they complete Grade 4.

IMPLICATIONS

1. Children can be taught to use acceptable theoretical models if the instruction provided is appropriate. The term appropriate here would include the use of mechanical models of either the static or dynamic varieties.

2. Since the level of achievement of Modelers consistently exceeds that of Non-modelers there appears to be a factor of time for acceptance or assimilation of this abstract idea. Children should thus be exposed to ideas of this type so they can make maximum progress throughout the educational program.

3. Children in Grades 2-6 with wide ranges of IQ's and varying levels of achievement in science and mathematics may be taught to use theoretical concepts in explaining physical phenomena when in the instructional procedure appropriate mechanical models are used.

4. It seems that the use of analogous models in teaching theoretical concepts serves to move the concept from the logical operations stage to the concrete operations stage for the child. This observation is supported by the lack of significance of IQ, grade level, age, and past achievement in science and mathematics to the learning that took place during this study.

5. Science curriculum programs for the elementary school may consider that children in Grades 2-6 can form theoretical concepts if provided with concrete experience analogies as a part of an otherwise appropriate program.

APPENDIX

The following excerpts have been taken from individual interviews during the process of selecting Modelers and Nonmodelers. The number designates the grade level of enrollment of the subject and M indicates that the subject was classified as a Modeler or N indicates that the subject was classified as a Nonmodeler; for example, 4-M designates a fourth-grade subject who was classified as a Modeler.

DEMONSTRATION OF EXPANSION OF AIR–
Balloon on Flask

4-M, Air in the bottle expanded. The air molecules would get bigger and push on each other. 4-M, The air might have little particles like a cloud. The group of particles could break apart and move all around. 4-M, When we heat the molecules of air in the bottle they bounce back and forth in the bottle and into the balloon.

4-N, The heat went through the jar and into the balloon. 4-N, The heat blows it up into the balloon. Little dots of water would evaporate and go up into the balloon. 4-N, Heat makes more pressure. There would be heat at the bottom of the bottle.

5-M, The little particles move apart from each other. They hit each other and go into the balloon. 5-M, The molecules in the bottle expand and move around and fill up the balloon. 5-M, The molecules got bigger and moved faster and went into the balloon.

5-N, Air turned into steam and pushed up the balloon. 5-N, the air went in from the fire and filled up the balloon. 5-N, Hot air causes the pressure to force the cold air up into the balloon.

6-M, The particles of gases are each expanding and going into the balloon. 6-M, The molecules need more room and push up into the balloon. The molecules are looser when heated. 6-M, When the air is heated the molecules move around faster.

6-N, The heat from the fire might have gone underneath the balloon and made the balloon rise. 6-N, More air must have been added to the bottle due to the heating. 6-N, The moisture in the air might have done it, like a teakettle.

DEMONSTRATION OF EXPANSION OF A SOLID–
Ball and Ring

4-M, There are real tiny things inside the ball that get bigger and make the ball get bigger. 4-M, The inside made the sides go out. The air and atoms pushed out the sides. There may not be air but there are atoms that separate. 4-M, Heat makes the molecules of the ball get bigger.

4-N, The heat would make it melt so it could stretch. 4-N, The fire makes it hot and it grows. 4-N, The ball expanded.

5-M, The molecules were moving around faster and that made it get bigger. 5-M, Molecules get heated and go faster and make the ball get bigger. 5-M, The molecules begin to separate when heated.

5-N, The heatness make it get bigger. 5-N, It got real hot and got bigger. 5-N, The ball got hot and connected to the other brass object.

6-M, It might be made of little particles. The molecules loosen up and need more room and push against each other. 6-M, Lots of little piec might get bigger inside. The particles o. chemicals grow when heated. 6-M, The molecules were moving faster and took up more room.

6-N, The pressure of the heat takes up the oxygen. 6-N, Steel gets bigger when put into a fire. 6-N, Air goes in and makes it expand.

DEMONSTRATION OF EXPANSION OF A LIQUID–
Flask and Water

4-M, The heat expanded the atoms so they went up in the tube. 4-M, The air cells in the water expanded and made the water go up.

4-M, It expands because little particles start coming apart when heated.

4-N, Hot water made it go up. The heat pushes it. 4-N, Heat on the bottom made the cold water go up. 4-N, Heat made the water go up.

5-M, The molecules begin separating in the water and it gets lighter. 5-M, The molecules of air in the water expanded and pushed the water up. 5-M, When the molecules of water get hot they expand and need more room because they move more.

5-N, The warm air pushed it somehow. 5-N, The heat might have sucked it like a vacuum cleaner. 5-N, The water got hot and started to rise.

6-M, The molecules move faster when heated and grow and that takes up more room. 6-M, The molecules or elements move faster when they are heated. 6-M, The water has atoms and molecules. It might rise because the molecules move faster.

6-N, Steam from the hot water forced the water up. 6-N, Tiny invisible bubbles pop open and have water inside that makes it go up. 6-N, Pressure from the hot water made it go up.

DEMONSTRATION OF EXPANSION OF AIR–
Balloon on Flask

3-N, The hot air made the air go up into the balloon. All of the air is pushed up. 3-N, Heat makes it go up. Heat made the air go into the jar and filled it up and some went into the balloon. 3-N, The fire builds more air. When the fire hits the jar air goes into the balloon.

2-N, The flame went right through the glass and made the balloon get bigger. 2-N, Air went in where the fire was. 2-N, The fire put more air into the bottle. The air got hotter and that made the balloon blow up.

DEMONSTRATION OF EXPANSION OF A SOLID–
Ball and Ring

3-N, The ball might get like a cake mix and bubble. 3-N, The ball melted and went out. 3-N, When it gets hot it gets bigger. It starts melting and gets bigger.

2-N, The heat started to soak in and blow up like the balloon. 2-N, The flame got it bigger. 2-N, The fire made the ball get bigger.

DEMONSTRATION OF EXPANSION OF A LIQUID–
Flask and Water

3-N, Heat makes it go up. It makes the water evaporate. 3-N, The heat pushed it. 3-N, The heat reached the cold and the water rose.

2-N, The weight made the water go up. 2-N, The water gets hot and the cold water goes up. 2-N, Hot water made it go up.

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