AN ANALYSIS AND CLASSIFICATION OF CHILDREN'S EXPLANATIONS OF NATURAL PHENOMENA

APPROVED:

Graduate Committee:

James H. Dougherty
Major Professor

Committee Member

Christine Planert
Committee Member

Dean of the School of Education

Robert B. Toullouz
Dean of the Graduate School
AN ANALYSIS AND CLASSIFICATION OF CHILDREN'S
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By

Robert Frank Smith, B. S., M. Ed.
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CHAPTER I

INTRODUCTION

Today's children live in the most complex and scientific environment the world has ever known. In their everyday activities they constantly come into contact with the phenomena of the natural world and the operation of scientific principles. They wonder, question, and explore, and they bring their curiosity and concern to the classroom.

Endless inquiries into the unknown and constant evaluation of the known have advanced every broad field of human knowledge and achievement. Child development and the teaching of science have not escaped this close scrutiny and evaluation. The advances made in the field of child development have always had an influence on the teaching of science. The objectives of both have always been affected by the social climate of the day.

Science in the elementary school at the beginning of the twentieth century had content and method that was based on the educational psychology then current, largely the recapitulation theory of G. Stanley Hall. It was
further grounded on the correlated belief that in the main part young children's questions were in the nature of "What is it?" This resulted in a definite claim that children could not interpret, and therefore the major aim of instruction and content should be to acquaint children with the names of objects and phenomena in nature. As a result, it was little more than nature study. Only with age were pupils able to benefit from instruction given containing information designated to answer such questions as "What happens?" and "What makes it happen?"

During the past decade such conclusions have been questioned by many authorities both in psychology and in elementary science. In addition, it has been found that there is mutual benefit from closer articulation between child development and elementary science.

Today many elementary school teachers encounter uncertainty and confusion concerning science instruction. This confusion is compounded in those schools that are still based on the idea that elementary education should be concerned only with the three R's, not with thinking and reasoning. Perhaps this is an indication of the need for an examination of children's explanations of natural phenomena.
Statement of the Problem

The problem of this study was to analyze the answers given by four groups (grade levels) of elementary school children and one group of adults (college freshmen) to direct questions regarding natural phenomena, to classify their explanations, to determine the methods and types of explanations used by these groups when they explain typical natural phenomena, and to compare these findings with the results of other investigators, especially Jean Piaget and Mervin E. Oakes.

Hypotheses

The basic hypothesis for this study was as follows: an analysis and classification of children's explanations of natural phenomena will not corroborate the interpretation that there is a definite stage in the child's thinking which is characteristic of a given age.

The following sub-hypotheses were also evaluated:

1. The responses given by all groups will tend to be naturalistic rather than enigmatic.

2. Experiments will elicit more cause-and-effect (physical) answers than will purely verbal questions.

3. Understanding of essential relationships will increase with age among children.
4. Children and adults in the highest quartile of their groups will give more physical explanations than those in the lowest quartile of their groups.

5. Differences between the explanations of children and adults will be largely of degree rather than kind.

6. Piaget's seventeen types of children's thinking will not be usable as categories for explanations given by subjects in this study.

Definition of Terms

For the purposes of the present study, the following definitions of terms were used:

1. **Highest quartile.**--Children and adults scoring at the point $Q_3$ to the highest score on the *Otis Quick Scoring Mental Ability Test* in their grade level will be considered to be in the highest quartile.

2. **Lowest quartile.**--Children and adults scoring at the point $Q_1$ to the lowest score on the *Otis Quick Scoring Mental Ability Test* in their grade level will be considered to be in the lowest quartile.

3. **Middle group.**--Children and adults not in either the highest or lowest quartile of their group will be considered to be in the middle group.
4. **Naturalistic.**—Responses that are non-metaphysical, matter-of-fact, in other words, those that are classified as being physical, will be considered naturalistic.

5. **Teleological.**—A belief that natural phenomena are determined not only by mechanical causes but by an over-all design or purpose in nature will be considered teleological.

6. **Physiographic.**—A description of the feature and phenomena of nature will be designated physiographic.

7. **Meteorological.**—Responses relating to or of the atmosphere or atmospheric phenomena will be labeled meteorological.

8. **Cause-and-effect.**—For the purposes of this study, responses classified as either complete or partial will be considered as indicative of a correct cause-and-effect relationship.

**Limitations of the Study**

Since primary-aged children constituted the main group of subjects in this study, and since the conversation-interview method was used, the number of subjects is necessarily small. This will set limits on the use and application of the findings.

No attempt was made to present an interpretation of the workings of the children's or adult's minds, but rather to analyze the nature of the responses themselves.
Conclusions based on the findings of this study are applicable only to the subjects examined or to similar groups in similar situations.

Major Assumptions

It was assumed that the investigator was capable and qualified to analyze and classify the responses given to the various questions and demonstration-experiments.

It was further assumed that the adult population was representative of college freshmen at North Texas State University during the fall semester, 1962.

Background and Significance of the Study

Interest in the development of causal thinking in children has been present for many years. At the turn of the century, G. Stanley Hall was advocating the idea of definite steps or stages in the area of mental development. These steps or stages closely paralleled the history of the human race and this thesis has been referred to as the recapitulation or stratigraphical theory. Since the middle twenties, Jean Piaget has been a leading proponent of this theory.

Increased interest in this area has been noted during the past forty years. During this period, certain
investigators, especially Mareannina Mogar (9), H. J. Hacker (3), and Wayne Dennis (1) have been and are convinced that the nature of the child’s mind is such that instruction relating to natural phenomena is largely futile.

The middle third of the twentieth century has also produced studies by Elli Herzfeld and Kate Wolf (5), I. Huang (6), Susan Isaacs (7), Jean Deutsche (2), and Angeline Keen (8) which have not agreed with all conclusions of the studies mentioned above. These studies indicate that there is a gradual and continuous development of intellectual abilities. As a result, instruction relating to natural phenomena may be of great value to the elementary school child.

Shortly before the outbreak of World War II, Mervin E. Oakes (10) conducted a study, the purpose of which was to analyze responses given by a group of children and adults to direct questions concerning various natural phenomena. He considered his work to be an extension of Piaget's (11) investigations. He reported some similarity between his findings and those of previous endeavors, but they differed considerably from those reported by both Piaget and Hall (4).
Since the time of the study by Oakes, innumerable scientific and technological achievements have transpired. Children today, because of television, other methods of communication, and the development of rapid transportation, have many experiences that their counterparts of a decade ago either never had or else encountered much later in life. This emphasizes the need to re-evaluate continually the wealth of knowledge available in the area of children's knowledge of the world in which they live.

Today the public is calling for more emphasis in the area of science instruction. The elementary school has not been immune to this demand. In order to meet these requests, it is necessary to investigate the knowledge, concepts, and misconceptions children have about their physical environment. The value of the teacher's learning from pupils should not be underestimated.

How the Present Study Differs from Others

The design of this study was closely patterned after the work of Oakes (10). It differs from that study in the following ways:

1. First-grade students were interviewed rather than kindergarteners.
2. The public school population came from a community about one-third as large as the previous study.

3. Intelligence quotients were available for all subjects. Scores were available for about two thirds of Oakes' subjects.

4. Modifications and additions were made to the questions employed by Oakes. Sixteen of the nineteen purely verbal questions and seventeen of the twenty-one demonstration-experiments employed by Oakes were used. In addition, two purely verbal questions were developed for this study.

5. The adult population was college freshmen rather than non-scientific college teachers.

6. Protocols were obtained verbatim using a tape recorder instead of being transcribed by hand.

7. The adult population was interviewed in two groups and recorded their own replies to questions. Oakes interviewed each adult individually and recorded their replies by hand.

Procedure for Collecting Data

Sixty-three children in grade one, seventy-nine in grade two, seventy-nine in grade four, and sixty-one in
grade six constituted the subjects for the major portion of this study. In addition, fifty-seven entering freshmen at North Texas State University in the fall of 1962 were examined.

All subjects were administered the Otis Quick Scoring Mental Ability Test. Students in grades one, two, and four received the Alpha Test, students in grade six the Beta Test, and the college freshmen the Gamma Test. Alpha intelligence quotients were obtained by the use of a conversion table.

Each elementary school child was asked the eighteen purely verbal questions and was queried about the seventeen simple demonstration-experiments. These questions covered a wide range of phenomena; three of the questions required a prediction prior to seeing the demonstration. The students were questioned individually using the conversation-interview method and their answers were recorded verbatim using a tape recorder. The machine and its microphone were placed as inconspicuously as possible in order not to distract students during the interview.

The adults participating in this study were questioned in two groups and were asked to record their answers on
paper without discussion. The questioning was comprised of seven simple demonstration-experiments, two of which were also presented to the elementary school population. Each question required the students first to predict the outcome of the demonstration-experiment. Following the prediction and the demonstration-experiment, the student was asked to explain the outcome regardless of the success of his prediction.

Procedure for Treating Data

Each subject's responses were transcribed from the tape recording and were typed on a separate sheet. These explanations were analyzed and classified according to one of the nineteen categories.

After the analyses and classifications had been made, percentages were computed to determine what types of responses were given by each group. An attempt was made to determine the incidence of naturalistic responses, i.e., those that are not abstract, abstruse, or subtle, in order to evaluate the first sub-hypothesis.

Separate percentages were computed for each group's responses to the purely verbal questions and to the questions concerning the demonstration-experiments. This was
done by tallying the number of complete and partially complete responses separately. These were used to appraise the second sub-hypothesis concerning the number of cause and-effect responses. Sub-hypothesis three, pertaining to understanding of essential relationships, was appraised using the same data.

Responses given by children and adults determined to be in the highest quartile of their groups were tallied separately from those given by children and adults scoring in the lowest quartiles of their groups. Percentages were computed using these tallies and were used to evaluate sub-hypothesis four which dealt with the number of physical explanations given by these two groups.

Percentages were computed for each grade level and also for the highest and lowest quartiles within each group. The data were compared to determine the similarity between children's and adult's explanations. Sub-hypothesis five was also evaluated by averaging children's responses in each of the three categories and comparing them with those of adults.

To appraise the last sub-hypothesis, Piaget's (11) seventeen types of children's thinking were used to classify the responses given by all subjects.
The value of the major hypothesis of this study was determined by studying the appraisals of the sub-hypotheses. Using data mentioned above and additional data, an attempt was made to discover any evidence present indicative of stages in children's thinking that was characteristic of a given age.

Summary, conclusions, and recommendations were based on the findings of this study.
CHAPTER BIBLIOGRAPHY


CHAPTER II

VARYING METHODS, PROCEDURES, AND RESULTS

AS REVEALED BY RELATED LITERATURE

Educators and psychologists have long been interested in the problem of the development of causal thinking in children, but it has only been in the last three decades that this area has been brought into the laboratory. One of the first investigators in this field was G. Stanley Hall (4). This was followed by Carla Raspe (25), but Jean Piaget and his co-workers (22, 23) have produced the most extensive series of laboratory studies. These pioneering endeavors have been followed by many others, indicating an ever increasing interest in this area.

Studies from Foreign Countries

A wealth of information has come from studies conducted in many countries throughout the world. The most famous of these is the work of Jean Piaget which has given rise to studies in many countries.

Raspe (25) presented the phenomena of color contrast and negative after image to children ranging in ages from
six to fourteen years. No numerical data are given but the explanations were placed into four categories. Three of these are naturalistic, and the fourth involves mysticism. Further study with interpretation of magical causality has produced an association between children's thinking and that of primitive peoples.

Using various purely verbal questions and demonstrations, Piaget (22) employed what he terms the "clinical method." Essentially this was a cross-examination of the subject to determine his thoughts and beliefs. Explanations elicited were classified into seventeen types. Piaget condensed these into seven categories: motivational, finalistic, phenomenalistic, participational, magical, moral, artificialistic, and animistic. These were considered characteristic of children before the age of seven or eight. Therefore, physical causality was non-existent because the child's thinking was prelogical and egocentric, which was greatly different from that of adults.

This finding coincided very closely with conclusions presented by Levy-Bruhl (15). His thesis was that primitive mentality was mystical, precausal, and prelogical.

Using dynamic explanations at the transitional form, Piaget (22) further asserted that the remaining eight types
of explanations (reaction of the surrounding medium, mechanical causality, generation, substantial identification, condensation and rarefaction, atomistic composition, spatial explanation, and logical deduction) were physical and mechanical. He also concluded that such conceptions, which he regarded as typical of civilized adults, make an appearance during the seventh and eighth year but do not become prevalent until the tenth or eleventh year.

Piaget has indicated his awareness of maturation, environment, and experience in matters concerning causal thinking. Despite this, he regarded the appearance of successive stages as being universal and inherent in the developmental process. In more recent writings, he has indicated a more liberal view in this area and has adjusted the ages at which various types of thinking occur.

Zeininger (37), using nine- and ten-year old children, asked various questions concerning meteorological phenomena and tadpoles. The investigator found a stage between the magical and causal which was characterized by "if-then" thinking. It was further determined that questions within the child's experience elicited realistic responses.
Isaacs (10) compared the behavior records of a group of children at the Malting House School at Cambridge, England. The number of children varied between ten and twenty and their ages ranged from two and one-half to ten and one-half years. The data indicated that children could and did apply knowledge already possessed to new experiences. It was further indicated that children increase their knowledge by experimenting, observing, and discovering. Evidence of mechanical causality was found at a much earlier age than was reported in the studies by Piaget (22, 23).

Expecting to find anthropomorphism and mysticism to stand out, Mead (17) gathered from Manus children free crayon drawings, interpretations of ink blots, and tried to shift blame to inanimate objects or to attribute will to them. Close observation of children engaged in many activities were recorded. Not only did the data reveal little tendency toward animism, but it revealed negative replies to explanations couched in animistic terms.

Werner (36), presenting many instances of the child's magical tendency, accepted Piaget's view of the explanations of children. Werner indicated a close parallelism between the mind of the child and that of primitive peoples the world over.
Using 260 kindergarten and public school nursery children and 146 public school children, Osaki (21) used a method based on Piaget's and Huang's (6) procedures. The children, ranging in ages from three to thirteen years, gave explanations that were classified either as physical or prelogical. Not until the sixth year of school did children give more than 50 per cent physical answers. It was concluded that children give prelogical explanations when they have no idea of the cause of the phenomenon.

Forty children and thirty illiterate adults were studied by Huang, Chen, and Yang (7) using the strange phenomena technique. The students, living in Hangchow, ranged in ages from five to twelve. Half of the subjects came from homes of the working class and half from a better socio-economic status. The adults ranged in ages from sixteen to thirty years and had just enrolled in night school. It was concluded that there was a high degree of similarity between these findings and those of Huang (6) despite the racial and cultural differences. They further concluded that there was no qualitative difference between the thinking of children and that of adults.
With subjects ranging in ages from six to nine years, Herzfeld and Wolf (5) used magical tricks to study causal thinking. They noted that many children failed to explain but instead merely reported the facts. All explanations were classified into three types: mythical, magical, and realistic. By age nine, 96.4 per cent of all responses were classified as being realistic. About one half of the responses were labeled realistic by age six, and two thirds by age seven. According to Piaget's thesis, they should only be beginning to appear at this age. Magical types of answers were considered to be somewhere between anthropomorphic and the scientific. This differed from Piaget, who classified this type as more primitive than anthropomorphic.

A study concerned with the superstitions of school children was conducted by Ter Keurst (33). A check list containing 92 superstitious beliefs was presented to 663 secondary school pupils ranging in ages from ten to nineteen years. The percentages of acceptance of the items for the various grades was found to fall between 14.4 per cent and 37.6 per cent. The incidence of acceptance was not shown to decline with chronological age or scholastic advances. In a follow-up study (34), the same author
matched fifty students, half of whom professed strong superstition and half of whom professed it only mildly. It was concluded that superstition is related to intelligence, scholastic success, socio-economic status, social adjustment, and personality development.

A study by Huang, Yang, and Yao (8) was devoted to the problem of the principles of selection which determine what concomitant events will be related causally by children in phenomenalistic explanations. An attempt was made to force phenomenalistic or "if-then" explanations by presenting them simultaneously with a number of irrelevant circumstances. Such a condition encouraged irrational explanations. Of 225 protocols, only six were found that could be classified clearly as being dynamism, animism, or magical causality.

One hundred eleven Japanese children ranging in ages from four to nine years were asked eleven questions pertaining to natural science by Syuniti (30). Six of the questions involved demonstrations. Subjects' answers were classified into seven categories according to the nature of the reasoning involved. From the results it was concluded that children establish their sensory understanding
at the ages of five to seven years, and it is developed into concrete understanding when they reach the ages of eight or nine years.

Lovell (16) conducted a follow-up study using ten of the experiments in *The Growth of Logical Thinking* (24) by Inhelder and Piaget. Four experiments were presented, individually, to 200 students, most of whom were between eight and eighteen years of age. The major stages in the development of logical thinking as presented by Inhelder and Piaget were substantiated. There were points of disagreement, however. Some of these were attributed to the possible differences in ability between the groups.

More than 1,200 children were asked a total of seventy questions in a study by King (13). These British children were queried about estimation of length, time and direction, and were asked about volume, weight, and shadows. The Otis Alpha Test A was administered to the majority of the subjects. It was reported that no evidence of Piaget's stages of development was found. It was also concluded that no evidence was found to substantiate Piaget's contention that there is a definite stage in the child's thinking which is characteristic of a given age. A
similarity was reported between responses of children and those of adults.

**Investigations in the United States**

A few studies concerned with children's explanations of natural phenomena appeared in this country prior to the work of Piaget. It was not until after this work that American researchers entered this field in great numbers.

Hall (4) attempted to discover the content of children's minds. With the aid of four trained kindergarten teachers and the assistance of sixty other teachers, he asked 134 questions of 200 selected subjects. The students were interviewed in groups of three and were merely checked according to whether or not they knew the answers to the questions asked. Hall concluded that children bring little of pedagogical value to school with them. He encouraged parents to acquaint their children with natural objects and instructed new teachers to discover what is already known by their students. It was further stated that concepts which are most common in a given locality are the earliest acquired, less frequent ones coming later.

The diary records of *Two Parents* (35) present evidence of a four-year-old child asking questions that needed
causal explanations. It was reported that animistic explanations were received concerning matters beyond the child's comprehension and of matters about which he could not experiment. But causal explanations were given when the child could manipulate, when he was interested, and when the matter was within his level of understanding.

Approximately fifty children ranging in ages from four to ten years, and ten college students were interviewed by Huang (6). Fifteen simple demonstrations involving strange phenomena were shown and the subjects were asked to explain the apparent violation of fundamental laws of nature. Piaget's seventeen types of children's thinking were found to be inadequate for the responses recorded. The explanations, rather, were placed into two categories, naturalistic and "if-then" explanations. It was concluded that the child's concept of reality and causality is naturalistic, factual, and logical, and is quite similar to that of the adult "man on the street" in many ways.

Johnson and Josey (11) replicated several of Piaget's studies and concluded that the results obtained by Piaget were not peculiar to the clinical method. Their findings
failed to substantiate many of those presented by the Swiss investigator. They suggested a difference in the intelligence quotients of the children may have accounted for the differences found. They further suggested that the English language is superior to French as an instrument for logical thinking.

Thirteen physical items with demonstration-experiments and seven psychological items were used by Keen (12) to study children's reasoning. The investigator administered the tests using 465 students in grades six through twelve and forty-two college sophomores. Multiple-choice tests were used in group situations. It was concluded that new experiences seemed to be assimilated too hastily, which led to illogical concepts or misconceptions. It was also stated that causal reasoning was not generalized ability but depends upon specific context of a given problem and upon a long array of specialized abilities. The importance of vocabulary in the ability to reason was also stressed.

In a study that is now considered to be almost a classic in this area, Deutsche (2) used eleven questions with demonstrations as one form of questioning and twelve questions without demonstrations as an alternate form. Slightly more than 1,500 children ranging in ages from eight to
sixteen years plus thirteen kindergarteners were questioned. An analysis of the data revealed Piaget's seventeen types of children's thinking not to be suitable for classification. When the responses were grouped into two categories, materialistic and non-materialistic, the percentages were, respectively, 61.9 per cent and 19.2 per cent for the kindergartener group, 81.3 per cent and 12.1 per cent for the eight-year-olds, and 85.2 per cent and 8.5 per cent for the fifteen- and sixteen-year-olds. It was further concluded that the types of explanations varied more from question to question than from age to age. This was attributed to the nature of the specific question which elicited the response rather than the child's general level of causal thinking.

Using primarily adolescents, Blachowski (1) administered a questionnaire on magical practices to approximately 120 subjects. The results indicated the tendency for magical thinking to decrease with age but a large number of the upper age group still professed to indulge in such practices. This study revealed the prevalence of some magical practices even among civilized adolescents and the author accepts Freud's view of tracing magical behavior to "pleasure thinking."
A study of children's learning of the cause-effect relationship was conducted by Lacey and Dallenbach (14). One hundred sixty children ranging in ages from five to nine years were asked to relate the cause of various events and occurrences. When a failure resulted, the experimenter gave the answer in the form of instruction. It was determined that children could learn this relationship near the end of the eighth year or at the beginning of the ninth year. It was further concluded that children between the ages of six and one-half and seven years had a probability of .5 of learning the relationship.

A series of studies designed to correct some of the methods and procedures used by previous investigators which had received criticism was conducted by Russell and his collaborators (26, 27, 28, 29). A uniform sequence of exactly worded questions was presented to more than one thousand subjects. The questions involved asking whether or not some twenty objects were living or dead and then a reason for the answer which was given. For other series there were similar questions concerning animism. It was concluded that individuals passed sequentially through the series of concept stages with increasing mental age and
chronological age. It was further stated that the stages of animism were related to both mental age and chronological age. The development of animistic concepts was found to be very nearly the same for urban, suburban, and rural children. The fourth study in the series (29) revealed, in contradiction to Piaget's findings, that children were more mature in their allied concepts than in animism.

Oakes (20) used the conversation-interview method to study children's explanations of natural phenomena. One hundred fifty-three students in kindergarten, and grades two, four, and six, and thirty-five adults were examined individually. Seventeen experiments and fifteen verbal questions were used and responses were recorded verbatim. Other features of this study were an analysis of the nature of the explanations as such, and an attempt to provide a basis for selection of materials for elementary science instruction. It was concluded that each subject, regardless of age, mental ability, or grade level, gave explanations of a wide variety of types. Piaget's seventeen types of children's thinking were not found to be usable as categories for explanations obtained and 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.

Mogar (18) investigated the age range from five to twelve years using sixty subjects. Three groups of ten pairs each were matched on the basis of chronological age, mental age, and sex. The control and experimental groups were presented the same questions with the exception of the experimental group being involved in a teaching situation. Findings of this study supported Piaget's view of the relationship of chronological age to the child's level of causal thinking. However, it was concluded that in some instances, contrary to Piaget's results, children younger than seven grasped laws from repeated observation of phenomena and used these laws to explain some event.

Elkind (3) divided eighty school and pre-school children into three age groups in order to replicate Piaget's investigations of the development of quantitative thinking. All subjects were tested using three types of materials (sticks, liquid, and beads) for three types of quantity. The results of this study were in close agreement with Piaget's findings that success in comparing quantity developed in three age-related, hierarchically ordered stages.
Determining young children's understandings of selected physical phenomena, and determining if typical instructional experiences were appropriate, too difficult, or too easy were the purposes of a study by Inbody (9). Fifty kindergarteners comprised the population, and the demonstration-interview technique was used. The evidence indicated that young children varied widely in the types of thinking they exhibited. This variation existed not only from child to child, but also within each individual. Most children gave explanations indicative of causal thinking and typical types of explanations appeared at an earlier age than in many previous studies.

Studies of Exceptional Children

A number of studies in this general area have been unique because they have been concerned with exceptional children. Study of the exceptional has always contributed to the knowledge gained through the study of the "average."

Part III of the series of studies by Russell (28) dealt primarily with feeble-minded individuals. On the basis of this study it was concluded that feeble-minded individuals were behind normals of the same chronological age in the area of causal thinking, but more advanced than normals of the same mental age.
With 120 children, sixty of whom were emotionally disturbed and sixty that were of normal adjustment, Nass (19) investigated three possible variables and their influence upon causality. These variables were personality, past experience with phenomena, and the wording of the questions. Each major group was divided into two groups, matched with regard to age, sex, and intelligence test scores. Each child was interviewed individually. One group received questions that were worded to begin with "Why." The other group received the same questions with the exception of their beginning with "How." It was concluded that the nature of causal thinking of withdrawn children was at a less mature level than that of normally adjusted children. Experience was found to be an important factor in causal thinking. Questions worded to suggest the operation of animistic forces elicited more responses that were classified as non-naturalistic than did questions not so worded.

Explanations of the cause of twenty-one physical phenomena written by 293 defective hearing and 565 hearing subjects between the ages of ten and twelve years were analyzed by Templin (31). Comparisons were made between
the explanations of the entire group and also between three matched groups, seventy-eight deaf, seventy-eight hard of hearing, and seventy-eight hearing subjects. Analysis was made using both the method of Piaget and that of Deutsche. The findings indicated the explanations of all subjects most frequently fell into phenomenalistic, dynamic, mechanical, and logical deduction categories. Logical deduction was shown to increase with age. Hard of hearing subjects resembled the hearing more closely than the deaf. It was further concluded that approximately the same results were obtained using both methods of classifications. As a result of Part II of this study (32), it was concluded that residential students used more of the lower levels of generalization than did students enrolled in the day school. Also, it was found that increased hearing loss was associated with more immature reasoning.

Summary of the Literature

Despite the investigations reported from such divergent locales as the Pacific Islands, the Orient, Europe, and the United States, it is evident that no one study has been produced that solved all the questions concerning the child's explanation of natural phenomena. Perhaps this
wealth of material is indicative of a need to extend the area of investigation.

This review of previous research in children's explanations of natural phenomena and related studies has produced some consistencies as well as some differences in terms of outcome. Some investigators support Piaget's contention that there are stages in the development of children's thinking characteristic of a given age. Others have found an overlapping of types of thinking both between age groups and in the thinking of the same child.

These inconsistencies concerning stages in the development of children's thinking gave rise to the major hypothesis of this study. The fact that some researchers consider there are real differences in kind between the thinking of children and adults prompted one of the sub-hypotheses of this study.

The study by Oakes was felt to be significant in this area and this paper is closely patterned after it. In order to determine the influence of the many technological and scientific developments that have been produced since the time of that research, several sub-hypotheses were based on the conclusions found in that study.
CHAPTER BIBLIOGRAPHY


The primary objective of this study was to analyze and classify responses given by children and adults to questions concerning natural phenomena, to determine the methods and types of explanations used, and to compare these with the results of previous studies.

This study was largely descriptive and qualitative rather than quantitative and statistical. Some of the problems for this study were presented as purely verbal questions while others were accompanied by simple demonstration-experiments.

Procedure

The description of the procedure includes aspects of the school environment, the conversation-interview, and the validation of the classifications.

The School Environment

The community from which the population for this study was drawn is located about midway between the cities
of Longview and Dallas, Texas. The 1960 census revealed the population of this community to be about 2,000. The town is nestled in the middle of an area noted for its vegetable crops and cattle. It lies just north and east of vast oil-producing areas. The community is almost totally dependent upon one large industrial plant which has a payroll of about 350 employees.

This community's elementary school has no syllabus or course of study in the area of elementary science. One of the major reasons for this is the belief that learnings in this area which are appropriate for one group will not necessarily be appropriate for another. Also, suggestions to teachers may be usable one year and quite unacceptable the next. The philosophy seems to be that instruction in all areas should be planned in terms of a particular group of children and should provide adequate opportunities for meeting the varied interest and needs of each one of these individuals.

The belief that "little" children can deal only with "little" ideas is not found in this system. Conversely, science instruction is based on the premise that a child's understanding of causes and relationships is greatly influenced by the number of interesting and meaningful experiences he encounters.
Content for the science program is chosen in order to meet the children's needs. It is chosen in terms of problems that are interesting, significant, and real for them. It comes from situations with which the children are familiar and in which they place importance. It is intended to contribute something to the children's lives in the community in which they live.

In many instances, the science program involves looking at everyday events and facts in a new way. This new way involves experimental thinking. This is true especially in the primary grades where the "let's find out" attitude is encouraged at every opportunity.

The Allyn and Bacon series Exploring Science (11) is available to all grades. These have been described as "the simplest, clearest, and most comprehensive elementary science texts that have appeared thus far" (10). In addition to this, the elementary school library was described as having 40 per cent of its total volumes dealing with science (9). The school is a member of the East Texas Co-operative Film Service and receives many useful films. Also, the school has a well stocked film strip library which contains many that are pertinent to science instruction.
Despite this wealth of audio-visual materials, they do not constitute the science curriculum. These are used only when they are appropriate and applicable. The focal point is the children and their experiences.

Teachers remain abreast of current thinking and methods in the area of science instruction through workshops. Personnel from East Texas State College have conducted these meetings. Although no definite amount is budgeted, teachers are rarely refused a request for science material or equipment.

Science usually does not have a regularly assigned period in the daily schedule of this elementary school. It is, instead, allowed to emerge spontaneously at various times depending upon the interest of the children or the events occurring in and around the school.

As is true in many school systems, teachers in this community approach the teaching of science with varying degrees of emphasis. Perhaps for this reason the science program was described by the superintendent as being "about average" (9). However, the results of this program were indicated when the school was pictured as being well above the national norm as determined by the S. R. A.
Achievement Series. At the end of the 1961-1962 school year, students in the sixth and seventh grades ranked in the 60th percentile or above on the science battery.

The Conversation-Interview

A concerted effort was made by the investigator to establish a high degree of rapport with the students. This included frequent visits to the classroom and informal chats on the playground. The establishment of friendly relations was aided by the teachers' stimulation of the children to look forward to the interview.

Once the children were in the room used for the interview, all irrelevant chatter was halted and the children were asked the purely verbal questions followed by the queries about the demonstration-experiments.

The same order of questioning was retained for all groups; children were not prompted or coached to answer in any way. Occasionally additional questions were asked to obtain a clearer meaning of the explanation given. Children were not told the appropriateness of their responses and their questions were answered as concisely as possible without giving information usable in answering subsequent questions.
Protocols consisted of question sheets on which the subjects' replies were typed. A tape recorder was used during the interview to insure a verbatim record of all answers and comments.

Validation of Classifications

In order to validate the investigator's classification of the responses obtained, a four-judge panel was selected. The jury was given copies of the definitions of the categories and copies of the responses of two students in each grade level. The students' responses were chosen randomly, one from the lowest quartile and one from the highest quartile of each grade level. The judges were asked to classify the thirty-five responses of each child by writing beside each the Arabic numeral of the type of explanation.

The judges were chosen on the basis of varying degrees of preparation and experience in science and child development. Judge A is a professor in the School of Education, North Texas State University, with considerable experience in the field of elementary education and the teaching of science. The remaining three judges are graduate students at North Texas State University. Judge B is
a doctoral candidate with a major in college teaching with a teaching field in science. Judge C is a doctoral student majoring in elementary education and is a former teacher and principal. Judge D is a graduate student majoring in biology.

Concerning the three major headings (physical, non-physical, and failure to explain), there was 87.41 per cent agreement between each judge and the investigator. In 8.15 per cent of the responses, agreement in three out of four judgments was obtained. In 2.96 per cent and 1.11 per cent of the responses, agreement in two out of four and one out of four judgments, respectively, was obtained. In only .37 per cent of the responses was there a failure to obtain an agreement with any of the judges.

Each decision had two subjective aspects, interpretation of the meaning intended by the subject in his response and interpretation of the definition of the category.

Within each major category there was 56.29 per cent agreement between all four judges and the investigator on all nineteen categories. In 9.26 per cent of the responses, agreement in three out of four judgments was obtained. In 15.19 per cent and 14.07 per cent of the responses, respectively, agreement was obtained. In 5.19
per cent of the judgments, there was no agreement between the classification of the investigator and the panel of judges. Where there was a difference in the classification of the investigator and one or more judges, 38.13 per cent of these disagreements were of one type. This involved the decision of whether or not to classify a response as being complete or partially complete.

**Design**

The design of the study included a description of the nature of the questions employed and a definition of the categories used in the classification.

**Nature of the Questions**

All questions used in this study, with the exception of two developed for this study, were taken from Oakes' (5) study. These, in turn, were adapted and modified from previous studies (1, 2, 3, 4, 7, 8).

The questions were of two kinds: (1) those that were entirely verbal; and (2) those based upon simple demonstration—experiments presented to the individual subject. The questions referred to natural phenomena of various types—biological, physiographic, meteorological, physical—and
required explanations. The questions covered the following areas: origin of the hills, motion of the waves, stream flow, cause of wind, moving clouds, flying airplane, telephone, nightfall, origin of trees, function of roots, function of flowers, function of the heart, and heavenly bodies.

The purely verbal questions utilized in this study were:

1. How were the hills and mountains made?
2. Where do waves come from?
3. Why does the water make waves?
4. Why does water in a stream or river move along?
5. Where does wind come from?
6. What makes clouds move?
7. How do the clouds stay up in the sky?
8. What keeps an airplane from falling?
9. How does sound travel in a telephone?
10. How does electricity travel?
11. Why does night come?
12. What do you do to get trees?
13. How does a tree begin?
14. What do roots do for the tree?
15. What are flowers for?
16. What does your heart do?
17. Why is the moon not always "full"?
18. Why can't we see stars during the day (5, pp. 7-8)?

Demonstration-experiments called for explanations about movement of the fingers, the anatomy of the hand, displacement of water, a U-tube, bubbles of air, gravity, force, air resistance, and centrifugal force.
The demonstrations and the questions presented to the elementary school-aged children were as follows:

1. (Ask child to move index finger.) How do you move your finger?
2. What makes it move?
3. (Hold child's fingers on electric light bulb.) Why are they so red?
4. (Place a tumbler full of water in a dish; have a rock about the size of an egg.) What will happen if I put the rock in the water?
5. (Put rock in tumbler.) Why did the water run out?
6. What will happen if I pour water in here? (One end of U-tube.)
7. (Show experiment.) Why does the water run up the other side?
8. (Same, but with cork in other end.) Why doesn't the water go up now?
9. (Blow through rubber tube into jar of water.) What is making the bubbles?
10. (Poultry drinking fountain—fill and tilt.) What are these bubbles?
11. (Boil water in a glass beaker.) What are these bubbles?
12. (Let ball drop to floor.) Why does it fall?
13. (Toss a ball.) Why does the ball move along instead of dropping straight down?
14. (Take two sheets of paper, same size; crumple one into a ball; hold even and release both at same time.) Why does this (crumpled) one fall faster?
15. (A one-inch cube each of lead and wood.) If I drop them both together, which will hit the floor first? Why?
16. (Lid of box attached to string at each corner; put a penny in lid and swing.) Why doesn't the penny fall out?
17. (Swing lid attached to string in horizontal plane, faster and faster.) Why does it go higher and higher (5, pp. 8-9)?
The college freshmen participating in this study were asked seven questions, all based on demonstration-experiments. Each question called for a prediction followed by an explanation of the outcome. The demonstrations and experiments were as follows:

1. I have a pad of scratch paper 3" x 5"; if I take two sheets (hold one in each hand), crumple one; then drop them both at the same time—how will they fall to the floor?

2. I have here two wooden boxes and a sheet of typewriter paper. If I place the paper on top of the boxes (placed six inches apart at the center of the table) and blow across under it (pointing along table top), what will happen?

3. I have here an ordinary empty spool and a small piece of cardboard. If I hold the card (supported by finger) under the spool and blow through the spool, removing finger when I start to blow, what will happen?

4. I have here a candle and a gallon glass jar, which is placed here (about four inches in front of candle, toward investigator). When I blow here (pointing at center of jar, bending forward so that the mouth is level with that point), what will happen?

5. Here are two cubes (one wood and one lead, same size, about one inch in diameter; then hold them up one in each hand). What will happen if I drop them at the very same time?

6. I have here a bottle, filled with water, in which there is a small glass vial, open at the bottom, and containing a bubble of air. (Cork is adjusted so that the vial is resting on bottom.) If I raise the cork just a little bit, what will happen?

7. For this experiment, you are the apparatus. Hold your hands so that tips of fingers are together; now fold middle (third) fingers down toward palms till second joints (knuckles) are
together; now move thumbs apart, without moving other fingers, and together again. From here on do not move any part of your hands as I ask you the next two questions: Can you move each of your fingers apart, as you have done your thumbs, without moving the others? (Subjects make prediction.) Subjects then try. How do you account for it (6, pp. 138-142, 190-195)?

**Definition of Categories**

Categories for classifying responses obtained in this study were taken from Oakes (5). These nineteen categories were grouped into three major headings following a procedure employed by Deutsche (1) and Keen (4).

The following is a list of the categories and their definitions:

I. Physical or Materialistic

1. Complete or direct. Such explanations will be those that are almost entirely dependent upon direct knowledge or facts and understanding of the phenomenon, and also upon an adequate vocabulary.

2. Partial or incomplete. These explanations will be those that are correct as far as they go even if the relationship indicated is of minor significance, or if in some cases irrelevant.

3. Trial-and-error or exploratory. This type of response will include those in which the subject may be considered as "thinking out loud," "groping blindly," even "guessing wildly," perhaps seeking cues from expressions of the examiner's face.

4. Personal. These responses will state the explanation in terms of the operator or individual human agent.
5. Analogy. In this category, comparisons, both simile and metaphor, may be given alone or as part of a longer response.

6. Simple phenomenalism. Piaget defines this as attributing causal relationship to some near-by object or accompanying event.

7. Human. Responses in this category will be those that ascribe the action to a bystander, a human invention, or a vague "they."

8. Reversal. This group will include an effect mistaken for the cause, or vice versa.

9. Trickery or legerdemain. All references to tricks of magicians and conjurers, as well as interpreting the result in terms of a change in the conditions of the experiment, will be entered in this category.

II. Non-Physical or Non-Materialistic

10. Dynamistic. These explanations will be those that are in terms of an impersonal force of some sort within the phenomenon.

11. Animistic, including personification. Included here will be explanations ascribing the characteristics of life to non-living objects; and human desires, etc., to things or animals.

12. Magical. Explanations placed here will be those that call upon some ill-defined, impersonal, mystical, external agency or power.

13. Religious. These will be explanations which refer to the Deity as the ultimate (or immediate) cause of a natural phenomenon.

14. Naturalistic. Interpretations on the basis of purposes are considered to be teleological. If the "design" or purpose given in the explanation is in the nature of things, it will be placed in this category.

15. Providential. This category will include those explanations which consider natural events to be designed for the benefit of mankind.

III. Failure to Explain

16. Obvious. Included here will be explanations in which the statement amounts to saying it is "just so," "just because," "it has to," etc.
17. Re-statement. Statements which merely rephrase the questions as a simple statement will be placed in this category.

18. Irrelevant. A statement will be classified here only if it seems entirely unrelated to the problem, not merely irrelevant to the true explanation.

19. "I don't know." Responses placed in this classification will be those that demonstrate a complete lack of knowledge (5, pp. 16-20.)

Within the first two major headings a further division may be noted. Under the physical heading the first five categories are operational and the next three are phenomenalistic. The first two categories under the non-physical heading are internal, the next two are external, and the last three are teleological.

Example Protocols

The following are example explanations from each grade level examined in this study. They indicate how the analysis and classification was completed. They reveal the differences between the various levels and also the differences within each individual.

First grade, verbal questions.

1. How were the hills and mountains made?
   "With dirt." Partial.

2. Where do waves come from?
   "The wind." Complete.
3. Why does the wind make waves?
"Because to make the fish cool." Naturalistic.

4. Why does water in a stream or river move along?
"'Cause the wind pushes it that way." Partial.

5. Where does wind come from?
"From the air." Phenomenalism.

6. What makes clouds move?
"Jesus." Religious.

7. How do the clouds stay up in the sky?
"Jesus holds them up there." Religious.

8. What keeps an airplane from falling?
"It has power." Partial.

9. What makes a telephone work?
"It has a telephone line." Partial.

10. How does electricity travel?
"Comes out of a pole." Partial.

11. Why does night come?
"So we can have sleep." Providential.

12. What do you do to get trees?
"Plant them." Complete.

13. How does a tree begin?
"Grows taller and taller." Partial.

14. What do roots do for the tree?
"It makes them grow." Partial.

15. What are flowers for?
"To make the yards smell good." Providential.

16. What does your heart do?
"It beats." Partial.

17. Why is the moon not always "full?"
"Because there can only be one man in there." Animistic.
18. Why can't we see stars during the day?
"Because there isn't room for them to be out."
Naturalistic.

First Grade, demonstration-experiments.

1. How do you move your finger?
"There's a bone in there that moves it." Partial.

2. What makes it move?
"Us." Partial.

3. Why are they so red?
"'Cause that light makes it red." Partial.

4. What will happen if I put the rock in the water?
"It will run over." Complete.

5. Why did the water run out?
"The rock made it come out." Partial.

6. What will happen if I pour water in here?
"It will run out over here (other end)." Complete.

7. Why does the water run up the other side?
"More water pushes the water up there." Partial.

8. Why doesn't the water go up now?
"'Cause the cork is in there." Partial.

9. What is making the bubbles?
"You." Human.

10. What are these bubbles?
"You pouring water out." Partial.

11. What are these bubbles?
"It's vibrating." Reversal.

12. Why does it fall?
"'Cause you dropped it." Phenomenalism.

13. Why does the ball move along instead of dropping straight down?
"You threw it." Phenomenalism.
14. Why does this one fall faster?
"'Cause it isn't spread out like that one." Partial.

15. Which will hit the floor first? Why?
"The wood; because, no the other stuff will; 'cause it's heavier." Complete.

16. Why doesn't the penny fall out?
"Because it's sticky in there." Trickery.

17. Why does it go higher and higher?
"Because you swing it and it goes swish." Partial.

Second grade, verbal questions.

1. How were the hills and mountains made?
"I don't know." I don't know.

2. Where do the waves come from?
"From the ground." Irrelevant.

3. Why does the wind make the waves?
"So the fish can swim." Naturalistic.

4. Why does water in a stream or river move along?
"I don't know." I don't know.

5. Where does wind come from?
"The sky." Phenomenalism.

6. What makes clouds move?
"The world." Partial.

7. How do the clouds stay up in the sky?
"I don't know." I don't know.

8. What keeps an airplane from falling?
"Its wings." Partial.

9. What makes a telephone work?
"Telestar helps." Partial.
10. How does electricity travel?
"From Telestar." Phenomenalism.

11. Why does night come?
"So we can have some rest." Providential.

12. What do you do to get trees?
"Plant them." Complete.

13. How does a tree begin?
"From its growth." Partial.

14. What do roots do for the tree?
"It makes them grow real big." Partial.

15. What are flowers for?
"Make the yard look pretty." Providential.

16. What does your heart do?
"Beats." Partial.

17. Why is the moon not always "full?"
"It's just not always full." Obvious.

18. Why can't we see stars during the day?
"'Cause it's day light." Complete.

Second grade, demonstration-experiments.

1. How do you move your finger?
"I don't know." I don't know.

2. What makes it move?
"I don't know." I don't know.

3. Why are they so red?
"The light." Partial.

4. What will happen if I put the rock in the water?
"It'll splash out." Complete.

5. Why did the water run out?
"'Cause the jar is full of water and the rock goes in and pushes the water out." Complete.
6. What will happen if I pour water in here? "Come up here (other side)." Complete.

7. Why does the water run up the other side? "The water makes it." Complete.

8. Why doesn't the water go up now? "You have that cork over there." Partial.

9. What is making the bubbles? "You're blowing through there." Partial.

10. What are these bubbles? "Water." Phenomenalism.

11. What are these bubbles? "Water." Phenomenalism.


13. Why does the ball move along instead of dropping straight down? "You didn't drop it straight down." Partial.

14. Why does this one fall faster? "Cause it's wadded up." Partial.

15. Which will hit the floor first? Why? "The lead." "I don't know."

16. Why doesn't the penny fall out? "It's stuck in the box." Trickery.

17. Why does it go higher and higher? "Because you make it go round and round." Personal.

Fourth grade, verbal questions.

1. How were the hills and mountains made? "By volcanoes or land pushing up." Complete.

2. Where do waves come from? "From the wind blowing or earthquakes under the sea." Complete.
3. Why does the wind make the waves?
   "I don't know." I don't know.

4. Why does water in a stream or river move along?
   "Because it's going slightly down hill." Complete.

5. Where does wind come from?
   "I don't know." I don't know.

6. What makes clouds move?
   "The earth turning and the wind blowing." Complete.

7. How do the clouds stay up in the sky?
   "They are too light to fall." Complete.

8. What keeps an airplane from falling?
   "The air going through its jets or propellers." Partial.

9. What makes a telephone work?
   "You speak into the mouth piece and the little wire takes the vibration to where you dialed." Complete.

10. How does electricity travel?
    "I don't know." I don't know.

11. Why does night come?
    "'Cause the earth turns." Complete.

12. What do you do to get trees?
    "Plant a seed." Complete.

13. How does a tree begin?
    "From a seed." Complete.

14. What do roots do for the tree?
    "The roots hold the tree in the ground." Partial.

15. What are flowers for?
    "To make things beautiful and to have honey." Providential.
16. What does your heart do?
"It pumps blood." Complete.

17. Why is the moon not always "full?"
"Because the earth shadows it." Complete.

18. Why can't we see stars during the day?
"The sun is brighter than the stars." Complete.

Fourth grade, demonstration-experiments.

1. How do you move your fingers?
"The muscles." Complete.

2. What makes it move?
"I don't know." I don't know.

3. Why are they so red?
"The blood shines." Complete.

4. What will happen if I put the rock in the water?
"Some of the water goes over." Complete.

5. Why did the water run out?
"The rock puts more, ah, puts more in and makes
the water run out." Complete.

6. What will happen if I pour water in here?
"It'll go down and the more you pour the higher
it goes." Complete.

7. Why does the water run up the other side?
"You poured it in and it went down and then up." Complete.

8. Why doesn't the water go up now?
"Because the air is trapped in." Partial.

9. What are these bubbles?
"You're blowing in it." Partial.

10. What are these bubbles?
"When you let air in." Complete.
11. What are these bubbles?
"The air at the bottom comes up." Complete.

12. Why does it fall?
"The gravity pulls it down." Complete.

13. Why does the ball move along instead of dropping straight down?
"Because you put energy behind it." Complete.

14. Why does this one fall faster?
"Because the other one is ah, flat and the air can't get by as easy." Complete.

15. Which will hit the floor first? Why?
"The lead; because it's heavier." Complete.

16. Why doesn't the penny fall out?
"Because when you swing it you swing it so fast it stays in." Partial.

17. Why does it go higher and higher?
"Because you put energy behind it." Partial.

Sixth grade, verbal questions.

1. How were the hills and mountains made?
"I don't know." I don't know.

2. Where do waves come from?
"The wind blows the water." Complete.

3. Why does the wind make waves?
"I guess because the wind blows and it rolls around." Partial.

4. Why does water in a stream or river move along?
"Because usually the river is down hill." Complete.

5. Where does wind come from?
"I don't know." I don't know.

6. What makes clouds move?
"The wind." Complete.
7. How do the clouds stay up in the sky?
"They are so light they float." Complete.

8. What keeps an airplane from falling?
"Power and the wind helps." Partial.

9. What makes a telephone work?
"Electricity in the wires." Complete.

10. How does electricity travel?
"It travels through the wires." Partial.

11. Why does night come?
"'Cause the sun goes around the other side of the world; actually the world turns." Complete.

12. What do you do to get trees?
"Find someone that has a little seedling." Complete.

13. How does a tree begin?
"It begins as a little seed." Complete.

14. What do roots do for the tree?
"They grow under the ground and get food for the tree." Complete.

15. What are flowers for?
"To make things pretty." Providential.

16. What does your heart do?
"It beats; it pumps blood into the body." Complete.

17. Why is the moon not always "full"?
"Because the clouds sometimes cover part of it." Partial.

18. Why can't we see stars during the day?
"Because the sun shines." Partial.

Sixth grade, demonstration-experiments.

1. How do you move your fingers?
"Little parts in our fingers take rush to our minds." Partial.
2. What makes it move?
   "Muscles." Complete.

3. Why are they so red?
   "I guess the way our hands are made." Partial.

4. What will happen if I put the rock in the water?
   "It will sink; the water will come out." Complete.

5. Why did the water run out?
   "Because there is something in there." Partial.

6. What will happen if I pour water in here?
   "It will come out the other side." Complete.

7. Why does the water run up the other side?
   "'Cause it hasn't got no other place to go." Partial.

8. Why doesn't the water go up now?
   "Because the air can't get to it." Complete.

9. What is making the bubbles?
   "Air." Complete.

10. What are these bubbles?
    "Air bubbles, too." Complete.

11. What are these bubbles?
    "Steam." Partial.

12. Why does it fall?
    "Gravity pulls it to the earth." Complete.

13. Why does the ball move along instead of dropping straight down?
    "I don't know." I don't know.

14. Why does this one fall faster?
    "It doesn't have anything to stop it; the flat one gets stopped." Partial.

15. Which will hit the floor first? Why?
    "The wood; I mean the lead one because it weighs more." Complete.
16. Why doesn't the penny fall out?  
"Because you swing it fast and the air keeps it in." Partial.

17. Why does it go higher and higher.  
"I don't know." I don't know.

College freshmen.

1. Why did the vial rise?  
"At first, pressure was much that the vial was suspended. After the pressure was let off, the vial went up." Complete.

2. Why did the wadded one hit first?  
"The uncrumpled one had a much broader surface area than did the crumpled one. Since the crumpled one was more compact--less surface area--it did fall first." Partial.

3. Why did the paper bend downward?  
"I think by blowing under the paper it somehow caused some kind of suction. Actually this is the only explanation I can think of." Partial.

4. Why did the card not fall?  
"The blowing causes more pressure inside of the spool. To equalize the pressure on outside, force of pressure is trying to get in or equalize; thus the paper stayed on." Partial.

5. Why did the candle go out?  
"As the candle was eating up oxygen, the wind was going for the candle for more oxygen. Or maybe as the wind went around the jar it caused a vacuum which put out the candle." Trial-and-error.

6. Why did they hit at the same time?  
"Newton's law of gravitation. The weight didn't make any difference except to speed up the acceleration, but they accelerated at the same rate, thus they hit at the same time." Complete.
7. How do you account for this?
"I believe the joints or bones of the hand are connected in such a way that will prevent the smaller finger than from the one down will result in not being able to move the finger next to the folded finger." Partial.
CHAPTER BIBLIOGRAPHY


6. __________, "Explanations of Natural Phenomena by Adults," Science Education, XXIX (April, October, 1945), 137-142, 190-201.


CHAPTER IV

ANALYSIS AND INTERPRETATION OF PROTOCOLS

The results of this study will be presented in three sections. The first section will report data assembled to evaluate the six sub-hypotheses. Section two will present an appraisal of the major hypothesis as determined by the sub-hypotheses and additional data. A brief summary will comprise the third section.

Sub-hypotheses

The first sub-hypothesis stated that responses given by all groups would tend to be naturalistic. All responses classified as being in the physical major category were considered to be matter of fact, non-metaphysical, in other words, naturalistic. Replies placed in the physical main category were those that were considered operational, phenomenological, or relying on trickery or legerdemain. Table 1 indicates the percentage of responses given by each group that were classified as physical, non-physical, and failure to explain. The data indicate that the percentage of responses classified as being physical increased
from 55.30 per cent in grade one to 75.67 per cent in the adult group. More than 50 per cent of each group's responses were classified as being physical, which was the criterion for a naturalistic classification. More than 75 per cent of the adult group's responses were placed in this category. This was almost matched by the sixth grade, which had 74.78 per cent of its responses so classified.

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Physical</th>
<th>Non-Physical</th>
<th>Failure to Explain</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>55.30</td>
<td>14.94</td>
<td>29.76</td>
</tr>
<tr>
<td>Second</td>
<td>59.80</td>
<td>8.19</td>
<td>32.01</td>
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<tr>
<td>Fourth</td>
<td>65.71</td>
<td>4.96</td>
<td>29.33</td>
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<td>Sixth</td>
<td>74.78</td>
<td>3.66</td>
<td>21.56</td>
</tr>
<tr>
<td>Adult</td>
<td>75.67</td>
<td>8.37</td>
<td>15.96</td>
</tr>
</tbody>
</table>

As the naturalistic responses increased with each higher grade level, there was a corresponding decrease in the non-physical replies. These, according to the criterion, were non-naturalistic replies. The one exception to this was
the adult group which had a greater percentage of non-naturalistic replies than any other group except the first grade. This can be compared with the relative stability of responses classified as failure to explain.

The percentage of responses classified in each of the nineteen sub-categories is presented in Table II.

**TABLE II**

FREQUENCY OF TYPES OF RESPONSES

<table>
<thead>
<tr>
<th>Type of Response</th>
<th>Grade One</th>
<th>Grade Two</th>
<th>Grade Four</th>
<th>Grade Six</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13.31</td>
<td>16.16</td>
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<td>4</td>
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<td>0.22</td>
<td>0.24</td>
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<td>9</td>
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<td>10</td>
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<td>12</td>
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<td>14</td>
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<td>15</td>
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<td>4.13</td>
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<tr>
<td>16</td>
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<tr>
<td>18</td>
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<td>0.75</td>
<td>0.63</td>
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<td>19</td>
<td>23.95</td>
<td>29.08</td>
<td>27.32</td>
<td>20.30</td>
<td>18.55</td>
</tr>
</tbody>
</table>
These data point out that the majority of responses were classified either as number one, two, or nineteen, that is complete, partial, or "I don't know."

When the responses were analyzed according to the type of question (purely verbal or queries concerning demonstration-experiments) the data presented in Table III were discovered. These percentages indicate that demonstration-experiments elicited more responses that are classified as being within the definition of naturalistic. Percentages

**TABLE III**

COMPARATIVE PERCENTAGES INDICATING THE TYPE OF RESPONSES ELICITED BY THE TWO TYPES OF QUESTIONS

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Physical</th>
<th>Non-Physical</th>
<th>Failure to Explain</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>44.82</td>
<td>24.66</td>
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<tr>
<td>Second</td>
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<td>Sixth</td>
<td>68.11</td>
<td>6.28</td>
<td>25.61</td>
</tr>
</tbody>
</table>

| Demonstration-Experiments | |
|---------------------------|--|----------------|
| First                     | 67.08 | 3.98 | 28.94 |
| Second                    | 69.95 | 1.58 | 28.47 |
| Fourth                    | 73.50 | .88  | 25.62 |
| Sixth                     | 82.27 | .72  | 17.01 |
for the adult population are not presented, since all questions presented to them were accompanied with demonstration-experiments. The table shows a difference in responses elicited by these two types of questions in favor of the demonstration-experiments. This type of question received an increase in percentage points ranging from 24.71 to 14.16 for grades four and six, respectively.

Tables IV and V are expansions of Table III and indicate the type of responses given to the two methods of questioning for all nineteen categories. These data reveal

<table>
<thead>
<tr>
<th>Type of Response</th>
<th>Grade One</th>
<th>Grade Two</th>
<th>Grade Four</th>
<th>Grade Six</th>
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<td>33.61</td>
<td>31.29</td>
<td>24.41</td>
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</table>
TABLE V
PERCENTAGE OF TYPE OF RESPONSE TO DEMONSTRATION-EXPERIMENT QUESTIONS

<table>
<thead>
<tr>
<th>Type of Response</th>
<th>Grade One</th>
<th>Grade Two</th>
<th>Grade Four</th>
<th>Grade Six</th>
</tr>
</thead>
<tbody>
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</tr>
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</tr>
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<td>0.79</td>
<td>0.82</td>
</tr>
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<td>6</td>
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<td>4.11</td>
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<td>0.08</td>
<td>0.00</td>
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<tr>
<td>8</td>
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<td>4.98</td>
<td>1.90</td>
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<tr>
<td>9</td>
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<td>0.95</td>
<td>0.40</td>
<td>0.72</td>
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<td>0.24</td>
<td>0.23</td>
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<tr>
<td>11</td>
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<td>0.32</td>
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<td>16</td>
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<td>0.71</td>
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<td>21.33</td>
<td>23.97</td>
<td>22.87</td>
<td>15.68</td>
</tr>
</tbody>
</table>

that, within the limits of the definition being utilized, both kinds of questions received responses categorized as naturalistic. These percentages further reveal that a higher percentage of responses to purely verbal questions were classified as type one, complete, then were responses given to questions concerning the demonstration-experiments. Conversely, the demonstration-experiments elicited a greater
percentage of type two, partial, responses than did the purely verbal questions.

These data tend to support the first sub-hypothesis in that there appears to be a greater percentage of responses given by all groups that can be classified as being naturalistic. Regardless of the grade level, answers given were matter of fact, non-metaphysical, rather than enigmatic.

These findings tend to support those findings of Oakes (11), Huang (5), and Deutsche (2). Oakes reported that although a few responses were enigmatic, the great majority were naturalistic. Huang considered children's responses to be, as a rule, naturalistic. Deutsche discovered about 60 per cent of all subjects' responses to be naturalistic.

It was stated in the second sub-hypothesis that demonstration-experiments would elicit more cause-and-effect answers than would the purely verbal questions. A response was considered to be indicative of a correct cause-and-effect relationship if it could be classified as either a complete or a partially complete answer. Table III revealed the percentages of responses classified as physical for the purely verbal questions was 68.11 per
cent for grade six. This can be compared with the lowest percentage of answers so classified as physical for the demonstration-experiments which was 67.08 per cent given by the first grade.

Since a response was considered to be physical if it was classified into one of the first nine types, Table VI indicates the percentage of responses given which could be determined as either type one, complete, or type two, partial, which was the criterion for a correct cause-and-effect relationship. Table VI reveals this information for the demonstration-experiments. First type one and type two are presented separately and then are combined.

**TABLE VI**

PERCENTAGE OF RESPONSES TO DEMONSTRATION-EXPERIMENTS DETERMINED TO BE INDICATIVE OF A CORRECT CAUSE-AND-EFFECT RELATIONSHIP

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Type One Complete</th>
<th>Type Two Partial</th>
<th>Complete and Partial Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>9.92</td>
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<tr>
<td>Adult</td>
<td>39.61</td>
<td>18.30</td>
<td>57.90</td>
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</tbody>
</table>
to reveal the percentage of responses classified according to this criterion. Table VI reveals that grades one and two had a relatively low percentage of type one but a higher percentage of type two. Grades one, two, and four had a higher percentage of type two than type one.

An examination of the data reveals that, for the criterion of this sub-hypothesis, the range in percentages is from slightly more than half for grade one to almost three-fourths for the sixth grade. It can also be seen that the percentage for the adults falls between those of the second and fourth grades.

A comparison of these statistics with those in Table VII, which gives the same information concerning the purely verbal questions, shows that the demonstration-experiments garnered a higher percentage of responses classified as revealing a correct cause-and-effect relationship than did the purely verbal questions. There was no basis for comparing the adult population's responses since they were presented only questions accompanied by demonstration-experiments. However, the remaining data indicate a tendency for the demonstration-experiments to elicit more cause-and-effect answers than the purely
TABLE VII

PERCENTAGE OF RESPONSES TO PURELY VERBAL QUESTIONS DETERMINED TO BE INDICATIVE OF A CORRECT CAUSE-AND-EFFECT RELATIONSHIP

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Type One Complete</th>
<th>Type Two Partial</th>
<th>Complete and Partial Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>16.31</td>
<td>19.58</td>
<td>35.89</td>
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<td>Two</td>
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<td>26.44</td>
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<tr>
<td>Six</td>
<td>33.33</td>
<td>26.87</td>
<td>62.20</td>
</tr>
</tbody>
</table>

verbal questions. The range for the former was from 74.69 per cent to 54.27 per cent as compared to a range from 62.20 per cent to 35.89 per cent for the latter. The significance of the difference between responses classified as indicative of a correct cause-and-effect relationship elicited by the demonstration-experiments and the purely verbal questions was found to be greater than the .01 level of confidence for the first, second, and sixth grades. The level of confidence for the difference in percentages given by the fourth grade was greater than the .05 level of confidence.
These findings are in agreement with a conclusion found in Oakes (11). It was concluded in that study that children, in explaining experiments which they had seen, gave a higher percentage of cause-and-effect explanations than they did in response to verbal questions.

Sub-hypothesis three conjectured there would be an increased understanding of essential relationships with an increase in age. For the purposes of this study, a complete or partially complete response was assumed to be indicative of an understanding of essential relationships. Tables VI and VII have revealed the percentages of responses of each group classified in these two categories. Table VI indicated an increase in percentage with an increase in grade level in the complete category in regard to demonstration-experiments. The size of the range was from 9.92 per cent for grade one to 39.61 per cent for the college freshmen. It also presented a decrease in partially complete responses in connection with the increase in complete answers. The size of the range was from 44.34 per cent for the first grade to 18.30 per cent for the adult group. When the two are combined, there is a steady increase of percentages until the adult group is reached. The percentage for this group is closely comparable to
that of grade two. Table VII reported the same information for the verbal questions. Grade one gave a higher percentage of complete responses than did grade two. In the partially complete category, the second grade offered a higher percentage of partially complete responses than did the fourth grade. However, when the two types of responses were combined, there is a gradual increase in percentages with each successive grade level. Table VIII reports this same information but with the two types of questions combined. Concerning complete responses, the table presents an increase with each higher grade level. Grade two gave the highest percentage of partial responses

**TABLE VIII**

PERCENTAGE OF RESPONSES DETERMINED TO BE INDICATIVE OF AN UNDERSTANDING OF ESSENTIAL RELATIONSHIPS

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Type One Complete</th>
<th>Type Two Partial</th>
<th>Complete and Partial Combined</th>
</tr>
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<tbody>
<tr>
<td>One</td>
<td>13.31</td>
<td>31.23</td>
<td>44.54</td>
</tr>
<tr>
<td>Two</td>
<td>16.16</td>
<td>32.39</td>
<td>48.55</td>
</tr>
<tr>
<td>Four</td>
<td>26.51</td>
<td>29.23</td>
<td>55.74</td>
</tr>
<tr>
<td>Six</td>
<td>36.16</td>
<td>31.92</td>
<td>68.08</td>
</tr>
<tr>
<td>Adult</td>
<td>39.61</td>
<td>18.30</td>
<td>57.90</td>
</tr>
</tbody>
</table>
while the college freshmen gave the lowest. When the two
types are combined, the table reports a higher percentage
for each grade level with the adults falling between the
fourth and sixth grades.

These data indicate that sub-hypothesis three is
substantiated. There was an increase of 4.01 percentage
points from the first to the second grade. This differ-
ence was found to be not significant. There was a dif-
ference of 7.19 percentage points from the second to the
fourth grade. This difference approaches the .05 level
of confidence. The 12.34 percentage points separating the
fourth and sixth grades were found to be significant at
greater than the .01 level of confidence. However, there
is a discrepancy present with the adult group. The college
freshmen gave only 2.16 percentage points more responses
than did the fourth grade and were 10.18 percentage points
below the sixth grade. Despite this fact, there is a
tendency, according to the criterion, for an increase in
essential relationships to increase with age.

Oakes' (11) contention that understanding of essential
relationships increases with age among children is supported
by these data. Oakes further noted that some answers given
by younger children were superior to those given by older children. The present study also corroborates this finding.

It was hypothesized in the fourth sub-hypothesis that children and adults in the highest quartile of their group would give more responses classifiable as being physical than would those in the lowest quartile of their groups.

Table IX, page 82, presents a comparison of mental ability and the percentage of responses given classified as either physical, non-physical, or failure to explain. It can be seen that the percentage for the upper quartiles in the physical category ranges from 39.53 per cent for grade one to 86.76 per cent for the adult group. In the lower quartiles the range was from 33.91 per cent for the first grade to 68.64 per cent for grade six. Table IX also reveals the wide range of responses to various questions given by these groups. The highest percentage given by the upper quartiles was 100 per cent while the lowest was zero per cent. The same was true for the lower quartiles.

Table X, page 83, reports the percentage of responses classified into the three major categories for the purely
### TABLE IX
MENTAL ABILITY AND TYPE OF RESPONSE

<table>
<thead>
<tr>
<th>Mental Ability</th>
<th>Range</th>
<th>Per Cent of All Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Grade One</td>
</tr>
<tr>
<td><strong>Physical</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highest Quartile</td>
<td>Average Per Cent</td>
<td>59.53</td>
</tr>
<tr>
<td></td>
<td>Highest Per Cent</td>
<td>100.00</td>
</tr>
<tr>
<td></td>
<td>Lowest Per Cent</td>
<td>0.00</td>
</tr>
<tr>
<td>Lowest Quartile</td>
<td>Average Per Cent</td>
<td>55.91</td>
</tr>
<tr>
<td></td>
<td>Highest Per Cent</td>
<td>93.80</td>
</tr>
<tr>
<td></td>
<td>Lowest Per Cent</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Non-Physical</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highest Quartile</td>
<td>Average Per Cent</td>
<td>12.63</td>
</tr>
<tr>
<td></td>
<td>Highest Per Cent</td>
<td>88.20</td>
</tr>
<tr>
<td></td>
<td>Lowest Per Cent</td>
<td>0.00</td>
</tr>
<tr>
<td>Lowest Quartile</td>
<td>Average Per Cent</td>
<td>12.31</td>
</tr>
<tr>
<td></td>
<td>Highest Per Cent</td>
<td>81.30</td>
</tr>
<tr>
<td></td>
<td>Lowest Per Cent</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Failure to Explain</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highest Quartile</td>
<td>Average Per Cent</td>
<td>27.84</td>
</tr>
<tr>
<td></td>
<td>Highest Per Cent</td>
<td>64.70</td>
</tr>
<tr>
<td></td>
<td>Lowest Per Cent</td>
<td>0.00</td>
</tr>
<tr>
<td>Lowest Quartile</td>
<td>Average Per Cent</td>
<td>31.78</td>
</tr>
<tr>
<td></td>
<td>Highest Per Cent</td>
<td>68.70</td>
</tr>
<tr>
<td></td>
<td>Lowest Per Cent</td>
<td>0.00</td>
</tr>
</tbody>
</table>
TABLE X

PERCENTAGE OF RESPONSES CLASSIFIED INTO THE THREE MAJOR CATEGORIES FOR THE PURELY VERBAL QUESTIONS ACCORDING TO MENTAL ABILITY

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Quartile</th>
<th>Physical</th>
<th>Non-Physical</th>
<th>Failure to Explain</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>Highest</td>
<td>49.69</td>
<td>22.54</td>
<td>27.77</td>
</tr>
<tr>
<td></td>
<td>Lowest</td>
<td>46.20</td>
<td>22.91</td>
<td>30.89</td>
</tr>
<tr>
<td>Second</td>
<td>Highest</td>
<td>54.70</td>
<td>15.78</td>
<td>29.52</td>
</tr>
<tr>
<td></td>
<td>Lowest</td>
<td>48.54</td>
<td>13.74</td>
<td>37.72</td>
</tr>
<tr>
<td>Fourth</td>
<td>Highest</td>
<td>62.71</td>
<td>7.79</td>
<td>27.50</td>
</tr>
<tr>
<td></td>
<td>Lowest</td>
<td>52.78</td>
<td>7.22</td>
<td>40.00</td>
</tr>
<tr>
<td>Sixth</td>
<td>Highest</td>
<td>79.97</td>
<td>6.29</td>
<td>13.74</td>
</tr>
<tr>
<td></td>
<td>Lowest</td>
<td>62.61</td>
<td>5.18</td>
<td>32.21</td>
</tr>
</tbody>
</table>

verbal questions according to mental ability. When these figures are compared with Table XI, which gives the same information for the demonstration-experiments, it can be seen that both the upper and lower quartiles gave higher percentages of physical responses to the demonstration-experiments than they did to the purely verbal questions. But the pattern still persists and those in the upper quartile of their group gave more responses classifiable as physical than did those in the lower quartile. The difference between the upper and lower quartiles of the first grade was found to be not significant. The difference
TABLE XI
PERCENTAGE OF RESPONSES CLASSIFIED INTO THE THREE MAJOR CATEGORIES FOR THE DEMONSTRATION-EXPERIMENTS ACCORDING TO MENTAL ABILITY

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Quartile</th>
<th>Physical</th>
<th>Non-Physical</th>
<th>Failure to Explain</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>Highest</td>
<td>70.60</td>
<td>1.47</td>
<td>27.93</td>
</tr>
<tr>
<td></td>
<td>Lowest</td>
<td>66.82</td>
<td>.39</td>
<td>32.79</td>
</tr>
<tr>
<td>Second</td>
<td>Highest</td>
<td>75.99</td>
<td>1.98</td>
<td>22.03</td>
</tr>
<tr>
<td></td>
<td>Lowest</td>
<td>66.45</td>
<td>2.31</td>
<td>31.24</td>
</tr>
<tr>
<td>Fourth</td>
<td>Highest</td>
<td>79.18</td>
<td>0.00</td>
<td>20.82</td>
</tr>
<tr>
<td></td>
<td>Lowest</td>
<td>60.63</td>
<td>2.50</td>
<td>36.87</td>
</tr>
<tr>
<td>Sixth</td>
<td>Highest</td>
<td>91.25</td>
<td>.42</td>
<td>8.33</td>
</tr>
<tr>
<td></td>
<td>Lowest</td>
<td>75.43</td>
<td>.42</td>
<td>24.15</td>
</tr>
<tr>
<td>Adult</td>
<td>Highest</td>
<td>86.67</td>
<td>5.09</td>
<td>8.15</td>
</tr>
<tr>
<td></td>
<td>Lowest</td>
<td>56.19</td>
<td>14.29</td>
<td>29.52</td>
</tr>
</tbody>
</table>

between these same two groups in the second grade was found to be significant at better than the .05 level of confidence. For the same two groups in the remaining three age levels, the differences were found to be significant at greater than the .01 level of confidence.

The results presented to evaluate this sub-hypothesis agree with a tentative hypothesis presented by Oakes (11). Based on a limited number of cases, that study concluded that bright children are more likely to give physical explanations than the less bright.
The difference between the explanations of children and of adults, stated the fifth sub-hypothesis, would be largely of degree rather than kind. Table XII presents the percentages of each grade level concerning the number of responses placed in the three major categories.

**TABLE XII**

**PERCENTAGE OF RESPONSES FOR ALL MENTAL ABILITY GROUPS CLASSIFIED ACCORDING TO THE THREE MAJOR HEADINGS**

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Group</th>
<th>Physical</th>
<th>Non-Physical</th>
<th>Failure to Explain</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>All</td>
<td>55.30</td>
<td>14.94</td>
<td>29.76</td>
</tr>
<tr>
<td></td>
<td>Highest</td>
<td>59.53</td>
<td>12.63</td>
<td>27.84</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>52.56</td>
<td>17.64</td>
<td>29.80</td>
</tr>
<tr>
<td></td>
<td>Lowest</td>
<td>55.91</td>
<td>12.31</td>
<td>31.78</td>
</tr>
<tr>
<td>Two</td>
<td>All</td>
<td>59.80</td>
<td>8.19</td>
<td>32.01</td>
</tr>
<tr>
<td></td>
<td>Highest</td>
<td>64.71</td>
<td>9.29</td>
<td>26.00</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>58.84</td>
<td>7.60</td>
<td>33.56</td>
</tr>
<tr>
<td></td>
<td>Lowest</td>
<td>56.97</td>
<td>8.36</td>
<td>34.67</td>
</tr>
<tr>
<td>Four</td>
<td>All</td>
<td>65.71</td>
<td>4.96</td>
<td>29.33</td>
</tr>
<tr>
<td></td>
<td>Highest</td>
<td>70.44</td>
<td>5.20</td>
<td>24.36</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>67.97</td>
<td>4.79</td>
<td>27.24</td>
</tr>
<tr>
<td></td>
<td>Lowest</td>
<td>56.47</td>
<td>5.00</td>
<td>38.53</td>
</tr>
<tr>
<td>Six</td>
<td>All</td>
<td>74.78</td>
<td>3.66</td>
<td>21.56</td>
</tr>
<tr>
<td></td>
<td>Highest</td>
<td>85.27</td>
<td>3.53</td>
<td>11.20</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>72.26</td>
<td>4.08</td>
<td>23.66</td>
</tr>
<tr>
<td></td>
<td>Lowest</td>
<td>68.64</td>
<td>2.94</td>
<td>28.42</td>
</tr>
<tr>
<td>Adult</td>
<td>All</td>
<td>75.67</td>
<td>8.37</td>
<td>15.96</td>
</tr>
<tr>
<td></td>
<td>Highest</td>
<td>86.76</td>
<td>5.09</td>
<td>8.15</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>66.33</td>
<td>10.23</td>
<td>23.44</td>
</tr>
<tr>
<td></td>
<td>Lowest</td>
<td>56.19</td>
<td>14.29</td>
<td>29.52</td>
</tr>
</tbody>
</table>
It also presents a breakdown according to mental ability for further comparison. It can be seen that the percentages for each grade level in the physical category range from 55.30 per cent for grade one to 75.67 per cent for the college freshmen. It is further shown that the differences between children's explanations and those of the adults ranged from a difference of 20.37 percentage points between the first grade and the adults to .89 percentage points between the answers of the sixth grade and the adults. No grade level gave less than 50 per cent physical responses.

The responses of adults classified as failure to explain are comparable to those of the first and second grades.

Table XIII presents another comparison between the responses of the children and those of the adults. This table presents average percentages for the groups of children as well as average percentages for the groups divided according to mental ability. The similarity between children's and adult's responses classified as physical, especially in the groups not designated as either highest or lowest quartile, is revealed. In this same category, a close resemblance can be seen between the lower quartile of each group. The difference between the responses classified
TABLE XIII

A COMPOSITE OF ALL CHILDREN’S RESPONSES CLASSIFIED ACCORDING TO THE THREE MAJOR CATEGORIES AS COMPARED WITH THOSE OF ADULTS

<table>
<thead>
<tr>
<th>Group</th>
<th>Physical</th>
<th>Non-Physical</th>
<th>Failure to Explain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Children</td>
<td>Adult</td>
<td>Children</td>
</tr>
<tr>
<td>All</td>
<td>63.90</td>
<td>75.67</td>
<td>7.94</td>
</tr>
<tr>
<td>Highest Quartile</td>
<td>69.99</td>
<td>86.76</td>
<td>7.66</td>
</tr>
<tr>
<td>Middle</td>
<td>62.91</td>
<td>66.33</td>
<td>8.53</td>
</tr>
<tr>
<td>Lowest Quartile</td>
<td>59.50</td>
<td>56.19</td>
<td>7.15</td>
</tr>
</tbody>
</table>

as being physical for all children and the adults was found to be significant at greater than the .01 level of confidence. A lesser degree of likeness is reported between the children and adults in the upper quartile. The table also indicates a high degree of resemblance between the adults and children in the non-physical category. Children in the lowest quartiles and those not in either the highest or lowest quartiles presented less non-physical answers than did the same adult group. The difference between the responses classified as being non-physical for
all children and the adults was found to be not significant. In the failure to explain category, almost twice as many of the children's responses were placed in the heading than those of the adults. There is a degree of similarity between the responses of the lowest quartile groups and those not in either the highest or the lowest quartile. A significant difference greater than the .01 level of confidence was found between the explanations of all children and the adults in this category.

These data tend to support this sub-hypothesis. The differences between the responses of adults and children seem to be one of degree rather than kind.

The data presented tend to substantiate the findings of several previous studies. Huang (5) concluded that, where a correct concept is lacking, the adult explains the event naively just as the child does. Similar conclusions have been presented by Keen (9), Able (1), Harter (3), Haslitt (4), King (10), and Johnson (8). Oakes (11) stated that whatever differences exist between the explanations of children and adults are largely, if not entirely, of degree rather than kind. Huang, Chen, and Yang (6) concluded there was no qualitative difference between the thinking of children and adults.
The last sub-hypothesis stated that Piaget's seventeen types of children's thinking would not be usable as categories for explanations given by subjects in this study. Piaget's seventeen types have been divided into three stages, the first two being characterized by pre-causality and the third by true causality. These types, listed in the Appendix, range from motivation which involves explanations in terms of motives, to explanations by logical deduction. Each type is a stage which leads finally to responses logically deduced.

The categories used in this study were devised by Oakes (11). They were suggested by, but not considered to be a compilation of, work of other investigators. Oakes' list includes several which are similar to Piaget's list. These are complete, simple phenomenalism, human, animistic, magical, and obvious, which correspond to logical, phenomenalistic, artificial, animistic, magical, and moral, proposed by the Swiss investigator.

An attempt to classify responses gathered for this study revealed many inadequacies in the list presented by Piaget. Table XIV presents an average of all groups' responses according to the nineteen categories utilized in
TABLE XIV

A COMPOSITE OF ALL CHILDREN'S RESPONSES CLASSIFIED ACCORDING TO OAKES' NINETEEN TYPES

<table>
<thead>
<tr>
<th>Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete or direct</td>
<td>26.35</td>
</tr>
<tr>
<td>Partial or incomplete</td>
<td>28.61</td>
</tr>
<tr>
<td>Trial-and-error or exploratory</td>
<td>0.34</td>
</tr>
<tr>
<td>Personal</td>
<td>1.61</td>
</tr>
<tr>
<td>Analogy</td>
<td>0.43</td>
</tr>
<tr>
<td>Simple phenomenalism</td>
<td>3.91</td>
</tr>
<tr>
<td>Human</td>
<td>0.38</td>
</tr>
<tr>
<td>Reversal</td>
<td>2.40</td>
</tr>
<tr>
<td>Trickery or legerdemain</td>
<td>0.80</td>
</tr>
<tr>
<td>Dynamistic</td>
<td>1.09</td>
</tr>
<tr>
<td>Animistic, including personification</td>
<td>0.29</td>
</tr>
<tr>
<td>Magical</td>
<td>0.39</td>
</tr>
<tr>
<td>Religious</td>
<td>2.55</td>
</tr>
<tr>
<td>Naturalistic</td>
<td>1.39</td>
</tr>
<tr>
<td>Providential</td>
<td>2.65</td>
</tr>
<tr>
<td>Obvious</td>
<td>1.03</td>
</tr>
<tr>
<td>Re-statement</td>
<td>1.03</td>
</tr>
<tr>
<td>Irrelevant</td>
<td>0.90</td>
</tr>
<tr>
<td>&quot;I don't know&quot;</td>
<td>23.85</td>
</tr>
</tbody>
</table>

This study. One of the most obvious shortcomings of Piaget's list is in the area of "I don't know." Since Piaget used the "clinical method," all subjects were questioned until some kind of answer was received. The table reveals that 23.85 per cent of all responses given by children for this study were classified in this category. When the last three types are combined, it can be seen that 25.78 per cent of the answers are included. None of
these could be classified according to Piaget's types. The only exception here is the possibility of placing some responses classified as irrelevant in one of Piaget's types. None of the responses so classified, which was less than 1 per cent of the total, could be placed into one of Piaget's types. Piaget's list also does not take into account responses of a religious nature. Although only 2.55 per cent of all responses were placed in this category, this figure is somewhat misleading since no adult gave a response which was so classified. Several questions elicited a high percentage of religious replies. This was especially true of questions dealing with the origin of trees and hills, and queries pertaining to flowers and nightfall.

Another area of disagreement dealt with the 28.61 per cent of responses classified as partially complete. These could not be placed in Piaget's logical category but also could not be inserted in one of the other sixteen categories. When these are combined with those mentioned previously, they constitute better than 50 per cent of all responses.

Piaget's list was found to be adequate for 33.15 per cent of all responses. This agreement resulted from the
similarity of categories between this list and Oakes'. Even with extreme liberalism Piaget's categories were found to be useful for less than 50 per cent of the responses.

This inability to use Piaget's categories is in agreement with other studies. Oakes (11) found the list devised by Piaget to be not usable for protocols collected for that study. Deutsche (2) reported that the seventeen types appear to be no longer useful.

Major Hypothesis

The basic hypothesis for this study stated that an analysis and classification of children's explanations of natural phenomena would not corroborate the interpretation that there is a definite stage in the child's thinking which is characteristic of a given age. Piaget has been the major proponent of this thesis. The Swiss investigator has stated that "true causality does not appear till about the age of seven or eight" (12, p. 267). It was further stated that prior to that age no genuinely physical explanation could be given. By the age of eleven or twelve the evolution to a truly causal explanation is reached.
Previously presented data have indicated that responses given by all groups tended to be naturalistic. A higher percentage of replies of the older children and adults fell into this category, but children of all ages gave some answers so classified.

Data which indicated there is an increase in the understanding of essential relationships with an increase in age have also been introduced. Despite this, children of all ages gave explanations that were indicative of a knowledge of essential relationships.

Table XV presents the percentage of responses that were classified as physical for each of the purely verbal questions utilized in this study. This table indicates the wide variety of responses given to various questions. Grade two produced a high of 96.2 per cent for the question concerning the function of roots. Grade four gave the same percentage for the question relating to the heart. For one question, pertaining to the purpose of flowers, grade two gave no replies classified as being physical.
### TABLE XV

**Percentage of Responses Classified as Physical for Purely Verbal Questions**

<table>
<thead>
<tr>
<th>Question</th>
<th>Grade One</th>
<th>Grade Two</th>
<th>Grade Four</th>
<th>Grade Six</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30.2</td>
<td>17.7</td>
<td>19.0</td>
<td>45.9</td>
</tr>
<tr>
<td>2</td>
<td>66.7</td>
<td>82.3</td>
<td>83.5</td>
<td>86.8</td>
</tr>
<tr>
<td>3</td>
<td>42.9</td>
<td>41.6</td>
<td>53.1</td>
<td>47.5</td>
</tr>
<tr>
<td>4</td>
<td>77.8</td>
<td>77.2</td>
<td>91.1</td>
<td>93.4</td>
</tr>
<tr>
<td>5</td>
<td>50.8</td>
<td>43.1</td>
<td>57.0</td>
<td>57.4</td>
</tr>
<tr>
<td>6</td>
<td>47.6</td>
<td>63.3</td>
<td>34.2</td>
<td>50.8</td>
</tr>
<tr>
<td>7</td>
<td>42.9</td>
<td>63.3</td>
<td>78.5</td>
<td>72.1</td>
</tr>
<tr>
<td>8</td>
<td>19.1</td>
<td>17.7</td>
<td>34.1</td>
<td>54.0</td>
</tr>
<tr>
<td>9</td>
<td>66.7</td>
<td>73.4</td>
<td>74.7</td>
<td>75.4</td>
</tr>
<tr>
<td>10</td>
<td>69.8</td>
<td>68.4</td>
<td>69.6</td>
<td>86.9</td>
</tr>
<tr>
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<td>39.7</td>
<td>65.8</td>
<td>58.3</td>
<td>75.4</td>
</tr>
</tbody>
</table>

The same information as found in Table XV except for non-physical replies is found in Table XVI. This table reveals that the first grade gave 64.2 per cent responses to the question concerning the purpose of flowers. At the same time, the second grade gave no non-physical replies to the questions concerning electricity and the function of roots. The fourth grade did the same for these two
### TABLE XVI

PERCENTAGE OF RESPONSES CLASSIFIED AS NON-PHYSICAL FOR PURELY VERBAL QUESTIONS

<table>
<thead>
<tr>
<th>Question</th>
<th>Grade One</th>
<th>Grade Two</th>
<th>Grade Four</th>
<th>Grade Six</th>
</tr>
</thead>
<tbody>
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<td>25.4</td>
<td>12.7</td>
<td>8.9</td>
<td>3.3</td>
</tr>
</tbody>
</table>

questions and also the questions pertaining to stream flow and the origin of trees. The sixth grade matched this and in three other queries, concerning wind, cloud movement, and nightfall, gave no replies placed in this major heading.

Table XVII presents the same information as the two previous tables for those explanations considered to be in the major heading labeled failure to explain. This table
TABLE XVII

PERCENTAGE OF RESPONSES CLASSIFIED AS FAILURE TO EXPLAIN FOR PURELY VERBAL QUESTIONS

<table>
<thead>
<tr>
<th>Question</th>
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<th>Grade Four</th>
<th>Grade Six</th>
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</thead>
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<td>32.8</td>
<td>21.3</td>
</tr>
</tbody>
</table>

reveals that 3.8 per cent of the second grade's responses for one query was so classified. Grade four gave only 2.5 per cent of their responses to one question and grade six had a low of 3.3 per cent for still another question. Grade two produced a high of 82.3 per cent for the question concerning the phases of the moon.
Table XVIII corresponds to Table XV except it presents information concerning questions based on demonstration-experiments. Grade six gave 98.4 per cent physical replies to one query concerning the demonstration-experiments.

### TABLE XVIII

PERCENTAGE OF RESPONSES CLASSIFIED AS PHYSICAL FOR DEMONSTRATION-EXPERIMENTS

<table>
<thead>
<tr>
<th>Question</th>
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<th>Grade Six</th>
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</thead>
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<td>81.0</td>
<td>64.6</td>
<td>58.2</td>
<td>63.9</td>
</tr>
</tbody>
</table>

This figure was closely matched by the other three groups.

For one question, grade one only gave 38.1 per cent replies placed in this division. Questions five and nine,
concerning displacement of water and air bubbles, respectively, elicited a high percentage of responses from all four groups. Question two, pertaining to the movement of the finger, produced a low percentage of responses for this category for all groups.

The percentage of explanations to demonstration-experiments that were classified as non-physical are found in Table XIX. Only two questions of the sixteen elicited

<table>
<thead>
<tr>
<th>Question</th>
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<td>1.3</td>
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</tr>
</tbody>
</table>
replies from the sixth grade that were classified as non-physical. Each of the four groups failed to give a non-physical reply to three or more questions. Two questions, concerning a U-tube and a poultry drinking fountain, received no replies classified as being in this major heading from any of the four groups. Grade one gave the highest percentage, 14.3, to the question concerning the movement of the fingers.

The percentage of failure to explain replies given to demonstration-experiment questions are presented in Table XX.

<table>
<thead>
<tr>
<th>Question</th>
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<td>17.4</td>
<td>34.1</td>
<td>40.5</td>
<td>36.1</td>
</tr>
</tbody>
</table>
For the first grade, one question elicited 58.7 per cent replies placed in this major heading while another question produced only 3.2 per cent. The lowest percentage was 1.6 per cent given by the sixth grade to a question concerning displacement of water.

These data indicate children gave a wide variety of responses to the various questions. They tend to support the main hypothesis which said there is not a definite stage in a child's thinking characteristic of a given age.

These findings support the conclusion of Oakes (11) that there was no evidence found to corroborate Piaget's thesis concerning stages in children's thinking. Isaacs (7) regarded Piaget's conclusions in terms of mental stages not to be borne out. Deutsche (2) concluded that no evidence was found that children's reasoning develops by stages. King (10) found no evidence that there is a stage in the child's thinking characteristic of a given age.

Summary of the Data

Data presented in this study indicate that children often respond to questions concerning natural phenomena with a physical answer. These responses are matter of
fact, non-metaphysical. Children were not shown to revert to the perplexing or the obscure to explain the events in their environment.

When answering questions concerning demonstrations they had seen, children gave a higher percentage of physical responses than they did to purely verbal questions. This fact indicates that children better understand principles when they are presented in concrete rather than abstract terms. This was further indicated by the higher percentage of complete and partially complete responses elicited by the demonstration-experiments.

The data support the hypothesis that an understanding of essential relationships is increased with age. This points out the need for a variety of experiences and the importance of vocabulary. Some children, who perhaps had a wider range of experiences, gave superior answers to those given by some older children.

Intelligence was shown to influence the percentage of responses classified as physical. By the same token, children and adults of all mental ages gave responses classified as physical. Children and adults in the highest quartile of their groups gave fewer replies that were placed in the failure to explain category.
The college freshmen in this study followed no definite procedure in explaining phenomena with which they were not familiar. Their responses resembled those of the elementary school-aged children in kind. There was a difference in degree but not one of great magnitude. One difference that was noteworthy was in the area of religious explanations. Children in all groups gave explanations of this type but no adult explained a phenomenon in this manner.

The data presented offered no evidence that there is a definite stage in the thinking of children that is characteristic of a given age. Each subject, regardless of age, sex, grade level, or mental ability, gave a wide variety of explanations. All groups gave all types of responses. Rather than being influenced by a mental structure for a given age, replies were affected by the problem, how the question was worded, by the child's experiential background, and his vocabulary development.
CHAPTER BIBLIOGRAPHY


CHAPTER V

SUMMARY, CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

This chapter is divided into four major parts. The first section consists of an over-all summary of the problem, procedure, and results. A presentation of the conclusions drawn from this study is given in the second section. Implications for science instruction in the elementary school are given in section three. Recommendations are presented in the final section.

Summary

The primary purpose of this study was to analyze the answers given by four groups of elementary school children and one group of adults to direct questions regarding natural phenomena, to classify their explanations, to determine the method and types of explanations used by these groups when they explain typical natural phenomena, and to compare these findings with the results of previous investigations.

This study was largely descriptive and qualitative rather than quantitative and statistical. No attempt was
made to present an interpretation of the workings of the children's or adult's minds. The nature of the responses themselves were analyzed to determine how children and adults explain typical phenomena.

The Otis Quick Scoring Mental Ability Test was administered to each subject participating in this study. Alpha intelligence quotients were obtained with the use of a conversion table. For each grade level, subjects were divided into three groups according to mental ability. These three groups were the highest quartile, the middle group, and the lowest quartile.

Each elementary school-aged child was asked thirty-five questions, eighteen of which were purely verbal, and the remainder were accompanied by simple demonstration-experiments. The adults were asked seven questions presented with demonstration-experiments. The questions were developed from queries used in similar investigations. The questions referred to a variety of natural phenomena and all required explanations.

Each child was interviewed individually and responses were recorded by means of a tape recorder. The same order and wording of questioning was presented to each child.
The adults were queried in two groups and recorded their responses themselves.

Responses collected were analyzed and classified according to one of nineteen categories. Each reply was then placed into one of the three major headings, physical, non-physical, and failure to explain. These major headings coincided with a practice employed in other studies concerned with children's explanations of natural phenomena. A four-member panel of judges validated the classifications of the investigator.

Intra- and inter-grade comparisons were made between grade levels to determine the nature of the responses given by the various age levels. Comparisons were also made between the subjects determined to be in the highest and lowest quartiles to determine the effect of mental ability on types of explanations offered. Percentages were computed and used as the bases for these comparisons.

The findings of this study do not corroborate the interpretation that there is a definite stage in the child's thinking which is characteristic of a given age. Each subject, regardless of age, grade level, or mental ability, gave a wide variety of responses. Explanations tended to
be influenced by the child's vocabulary, the nature of the questions and their wording, and the experiential background rather than age-related stages.

An analysis and classification of the data indicate that the majority of the explanations given are naturalistic. The subjects did not reply in terms of the perplexing, the abstract, or the abstruse. A further analysis revealed more cause-and-effect replies were elicited by the questions based on the demonstration-experiments than were given to the purely verbal questions.

The results of this study reveal, in general, that an understanding of essential relationships increases with age. However, there were instances where younger children gave superior answers to those given by older children. A computation of percentages indicated children and adults in the highest quartile of their groups gave more physical replies than did those in the lowest quartile.

Further computation and analysis revealed differences between the explanations of children and adults to be largely of degree rather than kind. Children and adults in the middle ability groups and in the lowest quartile were especially similar in the kind of responses given. An attempt to use Piaget's seventeen types of children's
thinking as categories for protocols of this study revealed them to be not suitable. They were found to be useful for only approximately one third of the responses given by subjects in this study.

Additional information obtained indicates that children are eager to learn more about natural phenomena. It was further indicated that instruction in this area would not be futile but rather would be very beneficial for children at these grade levels.

Conclusions

The following conclusions may be drawn from the present study:

1. The thesis that there is an age at which a certain type of thinking occurs was not corroborated.

2. Explanations given by all subjects were matter of fact, non-metaphysical, in other words naturalistic.

3. Questions based on demonstration-experiments elicited more cause-and-effect replies than did the purely verbal queries.

4. Understanding of essential relationships increased with age.
5. Children and adults in the highest quartile of their groups according to mental ability test scores gave a higher percentage of physical explanations than did those in the lowest quartile.

6. Differences of explanations of children and adults differed largely by degree rather than by kind.

7. Piaget's seventeen types of children's thinking were not found to be usable for classification of protocols of this study.

8. The results of this study are in agreement with previous studies, especially those by Oakes, Deutsche, Keen, and Huang. They do not agree with the findings of Piaget and Hall.

9. Purely verbal questions elicited more responses of a religious nature than did those based on the demonstration-experiments.

10. Explanations which referred to the Deity as the ultimate or immediate cause of a natural phenomenon diminished with increasing age.

11. Children's experiences and understanding often surpass their knowledge of words. A well developed vocabulary is an integral aspect of clear thinking.
12. Elementary school-aged subjects that lacked a concept or understanding made little attempt to guess or grope blindly for an answer.

13. Data presented indicate children are not only willing and capable to learn more about their physical environment but are also anxious to do so.

14. The contention that children's thinking is often characterized by animistic, including personification, explanations was not substantiated.

Implications

Since science was used as the vehicle for the investigation of children's thinking and explanations in this study, the results obtained seemed to justify certain implications for science instruction in the elementary school.

The findings of this study indicate that certain curricular practices and teaching methods in this area should be re-evaluated. It seems evident that children, in many instances, come to school with more information than is often realized.

The curriculum should afford children the opportunity to choose and solve their own problems. It should provide for exploration, manipulation, and experimentation with
the phenomena of the immediate environment. Data presented suggest children are better able to cope with experimentation and demonstrations than they are with abstract principles.

Data presented also indicate that children of any age group can profit from a study of any science problem in which they are interested. There are two limiting factors involved, the children's experiential background and the difficulty of the scientific principles involved.

The problem of what to teach at a given grade level can be solved by investigating the interests, knowledge, and misconceptions of the children. Children's interests and curiosities about the world and its content should be the bases for the curriculum.

Recommendations

The results of this study provide implications for further research in the following areas:

1. A similar study with subjects selected from a more urban population and findings compared with the present study as well as previous endeavors seems justified.
2. A similar study with subjects selected from junior and senior high schools and the results compared with the present and previous works would be helpful.

3. A similar study with elementary school teachers forming the adult population would be helpful for evaluating curricular practices and teaching methods.

4. A method should be devised to follow up replies given in order to obtain a clearer understanding of the intended explanation.

5. A method should be developed that would eliminate those "I don't know" responses where a partial answer exists.

6. A study should be conducted to discover what children are actually doing in the world of science when they are free to choose and to explore.
Piaget's Types of Causality Shown by Children*

1. **Motivational.**—Physical or other events are explained on the basis of motives.

2. **Finalism.**—Explanations in terms of the end products of phenomena.

3. **Phenomenistic.**—Contiguous phenomena are assumed to bear cause-and-effect relations.

4. **Participation.**—Objects which resemble each other are believed to act on or cause each other.

5. **Magic.**—The child endows himself with the ability to cause physical events.

6. **Moral.**—Explanations are given in terms of necessity.

7. **Artificial.**—An event is explained in terms of an intention behind it.

8. **Animistic.**—Attributing life or spirit to inanimate objects.

9. **Dynamic.**—Attributing force to objects but without the implication they are alive.

10. Reaction to surroundings.—The first true physical explanation in which a prime mover is the first cause followed by a mechanical explanation.

11. Mechanical.—Explanation by contact and transference of movement.

12. Generation.—Accounting for the origin of things by a transmutation of substances.

13. Substantial identification.—Bodies are born of one another but are no longer endowed with growth.

14. Condensation and rarefaction.—Physical objects grow from one another by condensing or rarefying.

15. Atomistic.—Physical objects are made of small particles—atomic theory.

16. Spatial.—Explanations of problems in perspective.

17. Logical.—Logical explanations of physical events based on empirical observation.
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Unpublished Material
