ELEMENTARY CHILDREN'S CONCEPTS
OF THE WATER CYCLE

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Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the Degree of
DOCTOR OF EDUCATION
May, 1991

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ACKNOWLEDGMENTS

I would like to express sincere thanks to the many people who helped in my work at Oklahoma State University, and especially to my adviser, Dr. Terence J. Mills. His patience, guidance, and understanding were key elements in the success of this research project. I also want to express appreciation to the other members of my committee, Dr. Russ Dobson, Dr. Vernon Troxel, and Dr. Dave Robinson, for their encouragement and suggestions.

I would also like to thank and acknowledge my parents, Virgil and Gertrude McJunkin, for their support and encouragement through the years.

A special thanks is due to my wife Dana who provided constant support, moral encouragement, and understanding.

Finally, I wish to thank Dr. Louis White without whose sense of humor, support, and companionship this venture could not have been undertaken and completed.

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CHAPTER I

INTRODUCTION

The general public has a high interest in but low level of understanding of science. Recent studies of the public understanding of and attitudes toward science portray a public deficiency in scientific understanding by even the simplest measures of scientific literacy. The Social Science Research Institute at Northern Illinois University defines scientific literacy for the general public as possessing a "reasonable vocabulary of scientific and technical terms—for example, the ability to define 'molecule,' 'atom,' or 'byte'—together with some knowledge of the processes and methods of scientific thinking" (AAAS, 1990). By these criteria, only the following percentages of the 2,000 Americans interviewed in 1985 qualified as scientifically literate: 3 percent of high school graduates; 12 percent of college graduates; and 18 percent of PhDs (AAAS, 1990).

The Water Resource

One area of science about which the public is particularly ill informed but which is of vital importance to all of us is that of water resources. It is important that the public be well informed so as to be able to make intelligent decisions about water resource management.

Water is probably the natural resource with which all are most familiar. All of us have had firsthand experience with it in many forms—rain, hail, snow, ice, steam, fog, and dew. We drink, cook, bathe, and wash away our waste with water; yet, in spite of our daily use of it, water is probably the natural resource we least understand. How does water get into the clouds, and what happens to it when it reaches the earth? Why is there sometimes too much and other times too little? Most important, is there enough high quality water for all the plants, animals, and people of the earth? The world's water supply in all forms (liquid, vapor, and ice) is tremendous. If this water could be distributed equally, every man, woman, and child on earth would receive 77 trillion gallons (Gartrell, 1989). However, since only about 0.003 percent (Gartrell, 1989), is available for human use a major problem lies in the availability and distribution of this water. Since water is a most essential resource for human survival, the small amount of usable water that is available to us is of the utmost importance.

Life developed on this planet within the protective environment water offers, and water is essential to the functioning of living things. Human beings require only about 1.9 liters (Gartrell, 1989) of water each day to sustain life, yet each year drought kills thousands of people and makes refugees of hundreds of thousands. Throughout the world the need for water continues to increase. Population growth brings demands for more water. Per capita use of water, especially in industrialized countries, is increasing rapidly. Forty percent of the world's population in 80 countries experiences serious droughts every year, and by the year 2000 the water situation will be much worse. With the world population escalating by 221,000 each day, a population the size of Mexico's is added to the world every year (Pariser, 1971). Increased population and the fact that much of the earth's available water is located in the wrong places or is of poor quality will continue to create critical water quality and quantity problems (Miller, 1985). We live in an age of scientific and technological innovation. Every phase of our lives is touched by the products and processes of these two enterprises. We hear about water pollution, acid rain, chemical contamination of drinking water, oil soaked beaches, and polluted rivers. Acid rain has increased the average acidity of lakes in the Adirondack Mountain region of New York by a factor of 100 since the 1930's. Many of these lakes are now almost as acidic as orange juice and can no longer support typical aquatic life (Gartrell, 1989). Most Americans do not know where their drinking water comes from, or how it gets polluted. Most of us do not understand that world water resources do have limits and, in many parts of the world, the limits are being reached. Even though water is a renewable resource, securing adequate supplies of good-quality water for drinking, washing, and manufacturing purposes is becoming increasingly difficult as earth's human population grows past the five billion mark.

Human beings require about two quarts of water per day to survive, but in the United States, the average person uses about 90 gallons each day at home. U.S. industries use over 330 billion gallons of water a day—a volume greater than half the average daily flow of the Mississippi River (Gartrell, 1989). Until recently in the United States, water has been easy to acquire and has been taken for granted. In our highly industrialized society, however, population and economic, technological growth have taken their toll on our water resources.

The media have attempted to warn the public about the necessity of water resource management. For example, The Los Angeles Times (Harvey, June 17, 1988) reported that sections of the United States, such as the West, Northern Plains, Southwest, parts of the Midwest corn belt, and Texas were especially dry and endured droughts aggravated by record high temperatures for the four years from 1984-1988. In July 1988, in Lincoln County, Idaho, some 400 irrigated farms ran out of water. For these farmers this meant only one instead of three cuttings of hay. Farmers also worry about having too much or too little rain (Harvey, 1988). Most of us know that the farm economy suffers during periods of drought, but not everyone is aware that much of the farmland in this country is subject to critical damage from erosion caused by the effects of rainfall.

According to Lawrenz (1986), one of the reasons the public does not feel well informed concerning water resources may be the lack of information they have received in elementary, junior high, and high school. The elementary school years play an important part in determining the level of public science literacy. If the quality of science instruction students receive in the early years is not high, students' basic science understanding will be shaky, and these students will be at a serious disadvantage (Lawrenz, 1986). An example of this low level of understanding of water resources was further noted in the results of a water resource knowledge test administered to determine the quantity and kind of knowledge possessed by recent high school graduates in Oklahoma. The level of knowledge of these high school graduates was low, particularly in the areas of water resource management and water's historical influence. The Water Resource Knowledge Assessment Instrument (WRKA) was administered to 159 recent high school graduates enrolled in their first week of university course work. The highest possible score on the WRKA test was 46. The mean score of 18.60 indicates that the sample population found the test difficult. Approximately 50 percent of the students scored 19 or less. Each item on the WRKA was assigned to a category within a conceptual framework for water (Mills, 1983). Of the 159 students, 80.9 percent had a correct response on the three questions (from a total of 46) within the category hydrologic cycle. The percentage of correct responses on the WRKA test by category indicated the relative knowledge of water cycle possessed by students was very low (Mills, 1983).

Water Resource Education

If we are to have clean, plentiful water for future generations, we must have a public well informed on issues related to water resources. Since it is the school children of today who will determine that future, they must be aware of the social, scientific, and technological concepts related to water.

One of the most recent developments in the study of how children learn scientific information deals with the concept of alternative conceptual framework. Piaget's research (1929) has led to widespread study of students' scientific alternative frameworks. Alternative frameworks are described as frameworks for conceptualizing experiences with the world which are at variance with the currently accepted scientific concepts. Piaget's early studies of children's explanations of natural phenomena and his studies dealing with causality have had the greatest impact on the understanding of the "alternative frameworks" that students bring to learning situations. Piaget was one of the first to learn that even very young children bring with them information which they use in answering questions in interviews (Posner, Strike, Hewson, & Gertzog, 1982). Studies have shown before children start to school they develop alternative frameworks which help them explain observations which they make about the water cycle, i.e., evaporation/condensation. Even without complete information, students will try to provide a sensible and coherent understanding of their world from their points of view. For example, a child may think clouds are made of cotton, or rain is God's tears. Regardless of whether the child is not yet in school or has been in school for several years, he/she may still construct alternative conceptual frameworks.

The alternative concepts that children hold may seem amusing but could be dangerous if not corrected (McCloskey, 1984). Furthermore, research clearly indicates that erroneous notions of various science concepts represent a potentially serious impediment to learning additional scientific information, which in turn becomes a serious problem in a science oriented society (Prather, 1985). In some cases, observations that children make might lead to logical and scientifically correct conclusions. However, many times children in school hold concepts that are incomplete or counterfactual. If these counterfactual concepts are to be dealt with, these "different" conceptual frameworks must be identified. It is necessary to help the learner modify these inaccurate concepts. If such concepts are not challenged, children will be hindered in making intelligent decisions about water resource issues which will affect the entire population. Citizens must have a working knowledge of science and mathematics in order to participate intelligently and responsibly in the decision-making process. A water knowledgable public could be a key factor in creating a long term, sustainable, high quality water resource. A misinformed public, armed with unaltered, inadequate water concepts will result in inappropriate decisions about management of the environment in general and water resources in particular. As a nation, we cannot afford to have illiterate citizens when it comes to water resource management.

Wise political decisions, which our children must make in the future, will depend on their understanding of water-related concepts. A first step to increase this understanding is to determine what concepts children hold about the water cycle and how accurate these concepts are. We must also determine how students acquire a proper conceptual framework of the water cycle and what factors enhance or detract from the process. If the concepts children hold and the concepts taught to children are accurate, the management of the precipitation available will be facilitated. Good management will in turn determine whether they have both the quantity and the quality of water to meet the needs of future generations.

The alternative frameworks that children hold are not always easy to discover. The fact that students can define science terms in a lesson and are good at taking tests does not necessarily insure that they understand concepts and will make a connection with real world applications as a result. If children learn science only by rote and what they learn is not applied to real world situations, they may revert to prior inappropriate alternative frameworks (Mintzes, 1984). As Osborne and Cosgrove (1983, p. 8) assert, "If scientific knowledge is to be anything but isolated facts, students need to develop conceptual models which they can test, and these conceptual models must be tested against real life experiences." Knowledge is inert when it is ". . . accessed only in a restricted set of contexts, such as solving word problems, and taking tests in the classroom" (Whorf, 1956, p. 17). Many of the models (demonstrations) which teachers use to teach science are not relevant to students because the children have no way to test the implications of these models in the real world. A survey of the research literature reveals that if "alternative conceptual frameworks" differ from appropriate accepted scientific concepts, there is a significant interference with learning the sciences (Biddulph, 1983). Therefore, for this reason it is imperative that educators, curriculum coordinators, and textbook authors be informed about the alternative conceptual frameworks that students hold. Information concerning alternative concepts will enable educators to identify possible conflicts between a student's concept about science and the one being taught in the science curriculum. As Ausubel, Novak, and Hanesian (1978, p. 43) state, "To find out what the students know about a concept and teach accordingly is the single most important principle for teaching."

Purpose of the Study

The primary purpose of this study was to identify, using a structured interview format, the water cycle concepts held by kindergarten, second, fourth, sixth, and eighth grade students. A secondary goal was to determine the relationships between water concept development and the following factors in the home and school environment: 1) score on the water cycle knowledge instrument, 2) sources of information in the home, 3) amount of school instructional time, 4) verbal ability, 5) child's cognitive development, and 6) age, gender, elementary achievement test scores, and parent's level of education.

Research Questions/Null Hypothesis

The following six questions and related null hypothesis direct the study. Questions 7 and 8 generate descriptive data; thus no null hypotheses were stated for them.

Research Question 1 and Ho-1

1. Is there a relationship between grade level and water cycle knowledge as measured by the water cycle score attained by the child?

Ho-1. Grade level is not significantly related to children's water cycle knowledge scores.

Research Question 2 and Ho-2

2. What are the cultural sources of information in the home that might relate to the child's notion of the water cycle?

Ho-2. Sources of information in the home are not significantly related to children's water cycle knowledge scores.

Research Question 3 and Ho-3

3. Is the amount of school instructional time spent on the study of water related to water cycle knowledge scores?

Ho-3. The amount of school instructional time spent on water cycle concepts is not significantly related to water cycle score.

Research Question 4 and Ho-4

4. Is there a relationship between mean verbal ability and water cycle knowledge?

Ho-4. The relationship between raw verbal ability score and water cycle knowledge score is not significant.

Research Question 5 and Ho-5

5. Is there a relationship between the child's cognitive development of spatial reference frames and water cycle knowledge?

Ho-5. There is not a significant relationship between ability to shift spatial reference frames and water cycle score.

Research Question 6 and Ho-6

6. Is there a relationship between the water cycle score and the age, gender, elementary achievement test scores, or parent's level of education?

Ho-6. There is not a significant relationship between water cycle score and age, gender, raw Metropolitan Achievement Test scores, or parents' years of education.

Research Question 7

7. What types of conceptual frameworks have children developed for the concepts involved in the water cycle?

Research Question 8

8. What proportion of pupils function at each of the conceptual framework levels of the water cycle interview?

a. Full understanding

b. Partial understanding

c. Specific Misunderstanding

d. No response

The data gathered to answer Questions 7 and 8 were descriptive in nature. Those data were not analyzed for statistical differences.

The study replicated, in part, the clinical interview method used by Osborne and Cosgrove (1983), Beveridge (1985), and Fenderson (1983). Osborne and Cosgrove investigated childrens' views of physical change associated with boiling, melting, dissolving, evaporating, and condensing. In a similar study, Beveridge studied the development of young children's explanations of evaporation. Fenderson's study dealt with children's concepts of earth and the misconceptions that children had concerning the earth as a finite body in space.

Like Fenderson's 1983 study, this investigation included interviews with kindergarten children. The current study used an interview format that identified kindergarten, second, fourth, six, and eighth graders' concepts of precipitation, condensation, evaporation, ground water, water treatment, change of state, and gravity. Since this was a qualitative study, the analysis of the empirical data was limited to a descriptive analysis of children's concepts concerning the water cycle.

Limitations of the Study

Limitations of this study were:

1. The subjects used in the study were students enrolled in a small rural school forty miles east of Oklahoma State University.

2. All students in classes participated and, therefore, no random sample was used.

3. The clinical interview method is a flexible method for interviewing students. However the method has problems associated with its subjectivity.

Definitions

The following terms are defined as they are used in this study.

1. Achievement - summary scores on the Metropolitan Achievement Test completed by subjects in 1987.

2. Alternative Conceptual Frameworks - conceptualizing experiences with the world which are at variance with the currently accepted scientific concepts (Archenholdand, Driver, Ortor, & Wood-Robinson, 1979).

A. Externally Dependent Framework - concepts that are at variance with the accepted scientific model. Inappropriate concepts that are formed after formal instruction. Also called misconceptions and misunderstandings (Fenderson, 1983).

B. Autonomous Frameworks - concepts that are self originated from personal experience in the absence of formal instruction. Also called naive concepts and children's science.

3. Appropriate Conceptual Frameworks - frameworks which are not at variance with the currently accepted scientific concepts. The frameworks are considered as either autonomous conceptual frameworks, or externally dependent frameworks.

A. Autonomous Conceptual Frameworks - concepts which are not at variance with currently accepted scientific concepts and are formed before formal instruction. Also are called pre-conceptions.

B. Externally Dependent Frameworks - concepts which are not at variance with currently accepted scientific concepts and are formed after formal instruction.

4. Concept Formation - organizing information about an entity and associating it with a label (word) (Marzano, Brandt, Hughes, Jones, Presseiser, Rankin, & Suhor, 1988).

5. Conceptual Frameworks - a person's schema which includes the appropriate conceptual framework, alternative conceptual frameworks, and no response.

6. Conceptual Framework Levels (Shepard & Renner, 1982) - each of the answers children given on the Water Cycle Interview were categorized into:

A. Full Understanding - responses that include all components of the validated answer (Validated Answers, Appendix A).

B. Partial Understanding - responses that include at least one of the components of the validated answer but not all of the components.

C. Specific Misunderstanding (alternative conceptual framework) - responses that includes irrelevant illogical or incorrect information.

D. No Response - the student does not have an answer.

7. Sources of Information in the Home Survey - a home survey of selected experiences which are encountered through home and community life (Appendix B).

8. Formal Instruction - instruction by a teacher in grades K through eighth.

9. No Concept - if the child has no verbal or overt action denoting the concept.

10. Parental Permission Form - a form sent to parents requesting permission for their children to be used in this study (Appendix C).

11. Schemata - mental knowledge structures or packages (Marzano et al., 1988).

12. Spatial Ability - the ability of a child to predict how the water level in a bottle will shift as the bottle is turned from a horizontal position to a vertical position (Appendix D).

13. Teacher Survey of Instructional Time - the teacher survey was used to determine the amount of time teachers spend on water cycle related concepts (Appendix E).

14. Validated Answers - scientifically validated water cycle concepts of the water cycle (Van Theil, 1990) (Appendix A).

15. Verbal Opposites Task - the ability of a child to think of a word that is the opposite of the one he/she are given. The more words a child can give the correct opposite to, the higher his/her verbal ability (Appendix F).

16. Water Cycle - the path of water as it evaporates and condenses to fall as rain upon the earth. Concepts included in the water cycle are groundwater, water/land ratio, evaporation, condensation, gravity, melting, freezing, water vapor, and boiling.

17. Water Cycle Interview Format - a structured clinical interview consisting of 30 pre-planned open-ended questions about the water cycle using demonstrations when appropriate and using real events whenever possible (Appendix G).

18. Water Cycle Score - score received on the Water Cycle Interview. The range of possible scores was 0 to 90.

19. Water Level Task - the instrument used to measure spatial ability. Spatial ability is how well the child shifts spatial reference frames as measured by the task (Appendix D).

CHAPTER II

REVIEW OF SELECTED LITERATURE

If the seeds of school science do not grow well,
perhaps it is because the ground in which they are
sown is already occupied by other species of ideas.
(Sutton, Clive; West , Leo, 1982)

Introduction

A review of related literature spanning 61 years (1929-1990) revealed information organized in the following categories: concept development and learning vocabulary, children's schema, students failure to learn science, alternative conceptual frameworks, importance of children's alternative conceptual frameworks, changing children's alternative conceptual frameworks in science, the elementary science teacher, and research on children's alternative frameworks. The discussion of these major categories is followed by a summary.

Concept Development and Learning Vocabulary

Linguists such as Whorf (1956), assert that language shapes perception, and support the position that vocabulary is one of the cornerstones of learning. A reality that previously did not exist is created when we impose a label on a phenomenon: "For better or for worse, when names are learned we see what we had not seen" (Condon, 1968, p. 31). Words shape perception. A person's vocabulary knowledge is an outward indicator of general aptitude (Anderson & Freebody, 1981) and vocabulary instruction can be a powerful tool in learning a particular concept (Stahl & Fairbanks, 1986). Therefore, an integral part of content-area instruction is teaching vocabulary which consists of concepts and the words that stand for those concepts (Marzano et al., 1988).

How does the above theory of teaching vocabulary differ from the educational concept of "meaningful learning"? We have words that stand for concepts, but these words do not describe the mental models of the concept. Teaching vocabulary does not necessarily mean teaching a concept. In Ausubel's (1968) book Psychology of Meaningful Verbal Learning, he distinguished between meaningful and rote learning in the following way: meaningful learning occurs when new knowledge is linked to relevant existing concepts in the learner's conceptual framework. Rote learning occurs when new knowledge which is linked to the students existing knowledge is not integrated into the existing cognitive structure. Rote learning is most likely to occur when new terminology is introduced. If objects, events, or regularities that words signify are not connected, the students do not acquire the concept that the label represents (Welch, 1981).

Roth (1985) found that in the area of science, even secondary students commonly do not grasp the relationships underlying scientific phenomena studied in class. He found that factual questions might be answered at a literal level of thinking. However, when new information that called for deeper understanding was presented, students failed to integrate the new information. They could repeat the word or definition that represented a concept, but were unable to go beyond a knowledge level of thinking.

If students are to experience meaningful learning, vocabulary knowledge is not enough. Memorizing synonyms or short definitions cannot be equated with in-depth learning of concepts. Rather, words must be treated as labels for concepts which are embedded in larger schemata. Instruction must aim at establishing rich ties between new words and prior knowledge and must present new words and concepts in the context of larger domains of knowledge (Nagy & Herman, 1984). Although Whorf (1956) asserted that vocabulary instruction is the cornerstone of learning/teaching, what must be remembered is that the word or symbol for a concept does not give a child an in-depth understanding of the concept being studied. Because a child knows all the words from a science lesson does not mean he understands the principles derived from these concepts. Students must have a richer understanding than only the word which stands for a concept. Can a concept exist without the person having a word for that concept? A person may be able to describe the process of evaporation without knowing the word evaporation. Another example is the word "robin." A robin may be known in many different languages by a student, but what does the person really know about a robin (Feynman, 1989)?

The same "word" may stand for a concept which starts out very simple, but grows, and grows, to become more complex. For example, when a third grader thinks of evaporation he might think of disappearance of water from a puddle. A high school student's idea of evaporation might involve molecules, heat, and water vapor. The "word" for the concept never changes, but the concept is fluid and dynamic.

Another point of view is that of Postman and Weingartner who suggested that meaning is not in the word. Rather meaning is in the minds of people. Whatever meaning a word has is assigned or ascribed to them by people. Words are not what they refer to, or as it is usually put, "the word is not the thing." The "mind" superimposes order on "reality." However, the order we impose on reality may distort it. For example, as children try to impose order on what they observe, this may create alternative concepts of reality. Requiring children to learn a definition and thus squelching deeper aspects of meanings encourages the belief that the scientific term constitutes the only part of its meaning that need concern the learner (Postman & Weingartner, 1969).

In addition, learning can become oververbalized forming verbal concept chains. These chains have no relationship with the actual situation, but are isolated ideas. The learner does not have a mental model of the word, even though he can use it in a sentence. Verbal superficiality must be avoided. A suggested technique for effective science instruction involves "learning by doing" (Dewey, 1938). Another is the recognition of the importance of the laboratory and the use of demonstration in teaching science. The concepts of science deal with the real world and therefore are more readily learned when instruction is based on operations that are equally concrete.

Concepts in their generalized form may be linked together in various ways to form principles. Principles are chains of concepts that make up what is generally called "knowledge." These principles represent the relationships among concepts, in all the variety these relationships may take. In a study by Katona (1940), it was shown that learners who simply learned the verbal statements for principles forgot most of them within a month, whereas those who learned the principles so they could demonstrate them showed almost perfect retention after the same interval.

To explain the relationship between concepts and principles individual labels would be given to concepts such as condensation, evaporation, water vapor, ground water and precipitation included in a unit of study on "Weather." At this level of learning these concepts would be at the "knowledge" level on Bloom's taxonomy (Hoover, 1980). In order to move into a higher level of the taxonomy (analysis, synthesis), relationships among or between the concepts must be discovered. When the student recognizes a relationship that applies to multiple examples, a principle is formed. Various generalizations can be formed from the words which represent concepts. We can imagine concepts as nodes of information that are stored in the mind (Figure 1). We might picture the concepts evaporation, condensation, clouds, ground water, water vapor, precipitation, and water in the following way:

GROUNDWATER

CLOUDS

WATER VAPOR CONDENSATION

PRECIPITATION EVAPORATION

Figure 1. Concepts as Separate Nodes of Information

These concepts could be interrelated and connected in the following ways: water evaporates into the air forming water vapor which condenses to form clouds in which water molecules form around dust particles and, when they become heavy enough, fall to the earth as some form of precipitation. Some of this precipitation sinks into the earth to form aquifers. If learning of the principle is to be expected, the child must already know the concepts involved. If a child does not understand the concepts involved he/she will learn the concepts as separate pieces of information or memorize them as definitions. The learner can know the word for the concept, but still fail to have a mental model of the processes involved in the concept. The purpose of effective instruction is not to have the student learn an isolated definition for concepts but rather a chain of concepts forming a principle. The following diagram illustrates how a child might arrange these concepts of the water cycle in his/her mind in a schema:

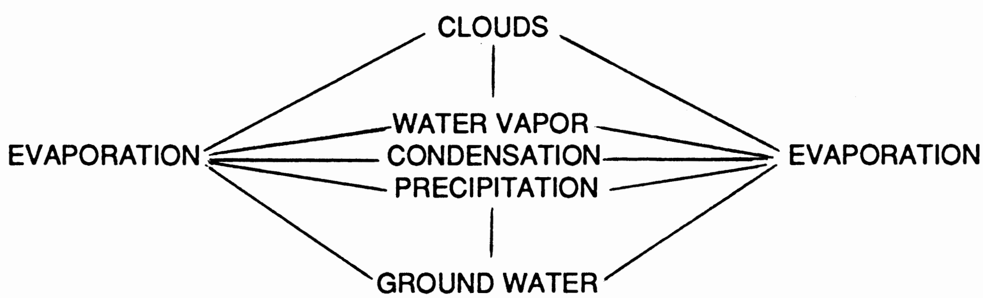

Figure 2. Concepts as Formed into a Schema in the Child's Mind

As shown in Figure 2, principles can be chains of concepts that can vary in length. A simple principle like *water evaporates* can be expanded to *water evaporates into the air forming water vapor which condenses to form clouds etc. . . .* which contains many more concepts than the original two, water and evaporate. Principles can also be divided into smaller parts called concepts. The learner can know a principle without necessarily being able to state it in exact verbal form. Knowing means being able to demonstrate or use it in various problem solving situations. Partial learning of a principle occurs when the student knows some of the component concepts of a principle but not other associated concepts. The prerequisite for acquiring the chains of concepts that constitute a principle is knowing the concepts. Otherwise, there is the danger that the conceptual chain, or some parts of it, will become merely a verbal chain, without full meaning. If the student can demonstrate the principle, it matters not if he\she can say the words which stand for concepts.

For elementary school children learning principles is often reduced to recall of statements in textbooks or lectures. The tests students take also represent recall of stated facts. Many educators contend that learning and testing must probe for the principle, not simply for the verbal sequence of concepts. This type of instruction of testing would not require memorization of facts and principles, but would cause students to analyze, synthesize, contrast, and compare concepts and principles.

Although single principles have been used as examples in the preceding paragraphs, most principles are not learned in isolation. Principles are usually learned as they pertain to a larger topic. What a student learns is organized knowledge. Organization of knowledge may be represented as a hierarchy or cycles of concepts which are interrelated with one another. The concepts in these principles must be understood before principles take on meaning for the student. Once a principle is learned it may be combined with another principle to support the learning of still another higher-level principle. These principles composed of concepts organized in this way form a hierarchy that may be called the structure of organized knowledge about a topic (Gagne', 1965). This structure of organized knowledge may represent a schema, or conceptual framework.

Children's Schema

The term schema (conceptual frameworks), can be used to denote a person's existing conceptual framework, as specific knowledge packages/structures which are the basis for our understandings, perceptions, fears, hopes, motives, and the root of all learning (Anderson, 1977;

Rumelhart, 1975; Smith, 1982). For example the schema for the word restaurant may include knowledge of different foods, different utensils, ordering food from different menus, different wine lists, and/or different ways of paying the bill. These components are part of the "restaurant" schema, which most Americans would find very simple. Suppose, however, you were from a Nomadic tribe in Egypt. Then you would lack a schema or mental model for "restaurant." The same would be true of Americans who, after moving to the desert would find it hard to form a schema for desert survival and would be confused about desert dining. Only when new knowledge is linked with relevant concepts already existing in the cognitive structure or schema does meaningful learning take place (Marzano et al., 1988). Therefore it is important to have knowledge of the "concepts" or "schema" existing in the minds of children.

According to Anderson and Freebody (1981), the mental schema used in remembering text information and in thinking can function in the following five stages:

1. Whenever subject matter learning is taking place a foundation of prior knowledge should be in place. New knowledge can be assimilated into existing structures. New information which is being listened to or read by the students is understood more easily by the existence of a schema.
2. Important aspects of the new material are focused on more clearly with the help of existing schema.
3. The existing schemata which allow orderly searches of the memory enhance the recall of information.
4. Summarizing and editing are thinking skills which are facilitated by the schemata.
5. Missing information or gaps in the memory are reconstructed. The schemata permit reconstruction and helps the learner generate hypotheses about the missing information (Marzano et al., 1988).

When information in a discipline changes over a period of time, or when "alternative concepts" must be unlearned, incorporating new information with the old can be a complicated process. Because students do not simply add new knowledge to what they know about a concept, they need to restructure information by formulating new questions, developing complex ways of thinking, and making inferences in order that this new material be incorporated into their existing schema. This process makes learning meaningful and allows schemata to change in structure, becoming more complex as new information is added (Greeno, 1980; Larkin, 1983).

Students' Failure to Learn Science

Studies on the status of science in public schools indicate that students are not learning science very well. The evidence cited in these studies includes poor achievement test scores and low enrollment in elective science courses. In addition, considerable attention has been focused on the declining scores of the Scholastic Aptitude Tests (SAT) (National Science Foundation, 1980, pp. 46-47).

The National Assessment of Educational Progress (NAEP) (1978) has provided excellent data for looking at trends in the area of science. Over the past 15 years, four different science achievement tests have been administered to samples of 9, 13, and 17-year olds. The resulting scores reveal small but consistent declines in knowledge of science concepts. The declines are greater for older students. Also reported was a steady decline in the number of students enrolled in science courses from 1960 to 1977 (Welch, 1979).

A number of educators are concerned that students at all grade levels are failing to understand the most basic scientific concepts (Champagne, Klopfer, & Anderson, 1980; Driver & Erickson, 1983). Part of the problem may be related to the way we assess students knowledge about particular concepts. Normally the way to find out would be to give them a paper and pencil test. However, written tests may not give an accurate picture of what students actually know. Often written tests measure little more than rote memorization of facts, not the pupils' full understanding of the concept being tested. Many students do well on tests which ask them to fill in a blank or circle the correct answer. However, when it comes to actually describing or predicting these physical events, students seem unable to understand (Champagne & Kloper, 1983). Although students may learn factual content and terminology in order to pass tests, their alternative conceptual frameworks interfere with their full understanding of scientific explanations (Eaton, Anderson, & Smith, 1983).

These alternative conceptual frameworks make sense to the student, so the student has no reason to reject them. We all make assumptions as to how the world works: "when the sky is cloudy and dark, it will probably rain"; or "people on the other side of the earth from us are upside down"; nails and cans rust when left in a cold damp place, so coldness must be responsible for the rusting process. Don't we say "I see the tree," rather than "I see the light reflected by the tree?"

These "Intelligently Wrong" (Ault, 1984), common sense answers are so attractive and convincing that when the correct concepts are encountered in the classroom they are molded to fit the "intelligently wrong" alternative frameworks. The responsible educator must be aware of the elusive nature of the alternative concepts of their students and be prepared to intervene, because "for the person who holds it, a misconception (alternative framework) feels like the truth—he doesn't know that he doesn't know" (Eaton et al., 1983, p. 7).

DeSessa (1982) stated that it is unrealistic to assume that erroneous concepts will disappear and be replaced by correct information in the routine course of science instruction. Why don't children accept new ideas or become influenced by a new concept being taught? Osborne and Wittrock (1983), have suggested three reasons:

1. There is no reason or motivation for children to change their ways of thinking. If their view of an experience satisfies them, why should they be interested in some one else's explanation?

2. Because the new information is not compatible with prior knowledge, only that part of the new concept which is compatible with the old is accepted. The remainder is rejected.

3. Sometimes the constructed meanings and knowledge structures in long term memory have minimal links. The concepts which connect the principles are not well developed, they are merely verbal chains. It could be said the student was "word rich" and "concept poor." Concepts are isolated and have no meaning except as isolated concepts. These isolated concepts are usually what is taught in science classrooms and tested by science examinations.

It is felt that major restructuring of children's ideas should to be undertaken before a sound understanding of a certain aspect of science will evolve (Osborne & Wittrock, 1983). We understand and act on our world in terms of our current knowledge structures or conceptions; they direct us to seek certain information and provide the basis for interpreting the information we encounter. Therefore, students with alternative frameworks cannot simply add new knowledge to what they already know. They must abandon frameworks that they have used successfully for many years in favor of new, more complex, and often instinctual ways of thinking. No wonder learning science is difficult. For many youngsters, school science is an obscure activity, full of statements by teachers and textbooks which are difficult to understand, which contradict personal views, and is thus not worthwhile. For example, Flegg (1981) found that for many of the children a demonstration depicting the water cycle using a boiling pan of water and a pie pan was an obscure activity which they could not relate to outside of the classroom. The consequence of continual instruction of this sort is that many children abandon the study of science at the earliest opportunity. Science can be meaningful for children only if it is logical or useful, not when it is magical and mystical (Watts & Gilbert, 1983, p. 161)!

Alternative Conceptual Frameworks

All elementary school children are exposed to at least some of the fundamental concepts of the water cycle, i.e., condensation, evaporation, water vapor, or clouds. However, children frequently approach the instructional situation with sets of autonomous ideas concerning these topics, or may develop "misconceptions" about them after formal instruction.

Not only is it important to clarify the misconceptions that children have about some of the fundamental scientific concepts, but clarity is also needed for the terms used to describe these "misunderstandings" that children have. The ideas that children have that differ from the accepted scientific view are described by a variety of terms in the literature.

For example, "children's science" is a term used by Stead and Osborne (1981) to denote a concept held before or after formal instruction. Gilbert, Osborne, and Fensham (1982) use the term "children's science" as part of conceptual structures which provide a sensible and coherent understanding of the world from the child's point of view.

Caramazza, McCloskey, and Green (1981) used the term "naive principles" to describe the many misconceptions held by people with no formal instruction in physics, as well as many who have completed high school or college physics courses. Mintzes (1984) use the term "naive theories" for ideas children may have which are opposite of the scientifically accepted theory and uses the term to denote an idea the child has before beginning school. Champagne and Klopfer (1983) used the term "naive conceptions" to identify ideas about the natural world that students bring with them to the classroom.

The terms "misconception" and "preconception" are used in a range of situations to denote elementary models or theories which are in error. Marek (1986) uses the term "misconception" to describe a misunderstanding either before and after formal instruction. Ausubel (1968) used the term "preconception" to describe ideas which are a result of incorrect observation or illogical thought. Flegg (1981) uses the terms "preconceptions" and "misconceptions" interchangeably in describing how children bring incorrect explanations about how the world works to school.

"Pre-conceptions" as described by Prather (1985), refer to knowledge students have before formal instruction. Anderson and Smith (1985) used the term "preconception" to refer to ideas students bring to instruction while in school.

Strauss (1982) discussed childrens errors in terms of their usefulness in revealing conceptual frameworks. He described perceptually driven "misconceptions" as seen when a student is overloaded with so much information that he cannot attend to the relevant ones.

Smith referred to these misconceptions as "mis-perceptions," because the student fails to to go beyond the difficulties encountered at the perceptual level. According to Smith, children also construct stunted conceptions, or limited viewpoints which focus on only one part of a larger system. These viewpoints are often logically coherent, but are limited and thus incorrect (Smith, 1984). "Alternative frameworks" was used by Driver and Easley (1978), as an all inclusive term to describe the misunderstood terminology commonly used in science education.

Although there is no agreed upon use of this terminology found in the literature there are some common characteristics which have been recognized. Among these characteristics are the use of everyday language to interpret science concepts (sometimes attaching naive meaning to technical terms), egocentric, anthropocentric, and animistic viewpoints, the tendency to dismiss non-observables as nonexistent, and the endowment of objects with a certain amount of physical quantity.

To help clarify these characteristics, Figure 3 denotes, through schematic mapping, how terminology concerning children's conceptual framework will be used in this study. Figure 3 outlines the view that information is organized into conceptual frameworks. The framework is considered as either an appropriate or an alternative conceptual framework. The acquisition of acceptable concepts may be made through a personal "autonomous" act prior to and outside of formal "externally" initiated concept formation such as occurs in school. Subsumed under autonomously appropriate concepts are those formed before formal instruction called pre-conceptions. Alternative concept formation may also be viewed as being autonomously or externally derived. Subsumed under alternative autonomous conceptual frameworks are similar terms, naive and children's science. In the literature these terms are used to describe the construction of concepts in the absence of formal school instruction. Autonomous conceptual formation is to be admired, nurtured and respected, and in the opinion of the author, the term misconception, mistake, or misunderstanding should never be used to denote an autonomously derived concept! Externally alternative conceptual formation is considered to happen after formal school instruction. Subsumed under external alternative concepts are the similar terms of misconception and misunderstanding.

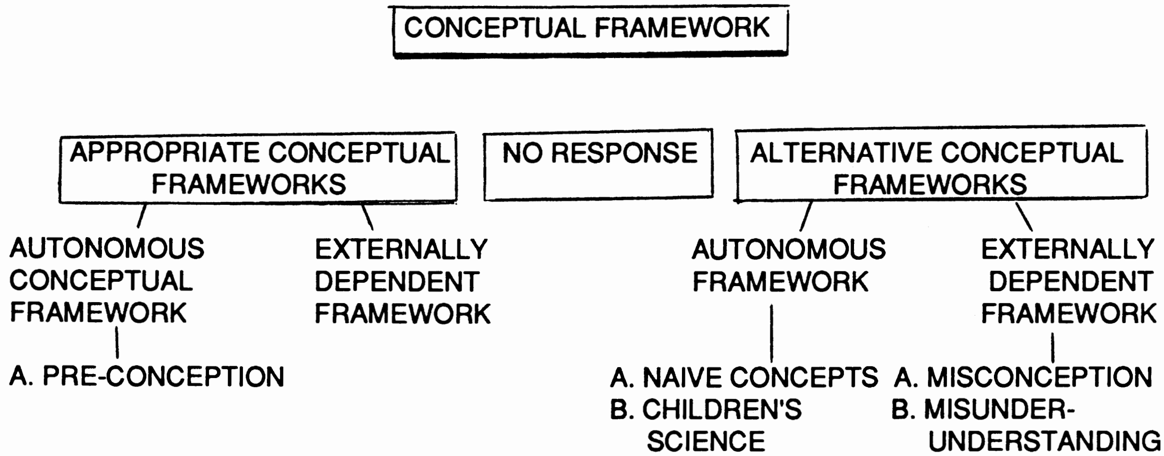

Figure 3. How Terminology will be Used in this Study

Common misconceptions in various areas of science reflects the fact that the term "misconceptions" tends to be used in studies where students have been exposed to formal models or theories and have assimilated them incorrectly. When students have developed autonomous frameworks, or externally alternative dependent frameworks for conceptualizing their experience of the physical world these are called "alternative conceptual frameworks" (Driver & Easley, 1978).

Importance of Children's Alternative Conceptual Frameworks

When introducing a new concept, it is important for the teacher to consider what the children already know and determine if what they know about the concept is scientifically correct. Concerning what children already know, Griffiths and Grant (1985), express these thoughts:

> There is however a growing recognition that it is not merely the absence of appropriate mental operations, concepts or skills which inhibits learning; the presence of previously acquired theories, information and skills which may be incorrect or inappropriately applied may actively interfere with the acquisition of new material (p. 179).

Traditionally it has been assumed that "prior knowledge" will facilitate further learning (Champagne & Klopfer, 1983). However, if this prior knowledge conflicts with what is being taught, "alternative conceptual frameworks" may develop. Extinguishing an existing concept is not easily accomplished. If a new content is learned and cannot be woven into what the student already knows, "meaningful learning" will not take place. Understanding and comprehending involves interpreting information subjectively and relating it to what we already know. Driver and Easley (1978) cited evidence that children at a very early age construct mental models formulated as sets of expectations about natural phenomena in an effort to make sense of everyday experiences. Using the work on trajectory of objects, it has been shown that students' prior knowledge can interfere with their ability to learn science (Champagne & Klopfer, 1980). Teachers of fifth grade students should not assume knowledge acquired in fourth grade is completely accurate, or was integrated accurately by the student. Teachers should always be aware of students prior knowledge and how it will effect what is to be learned.

"Teacher Dominance" theory assumes that learners may have some conceptual view of a new science topic before it is taught, but that this understanding has little significance for learning and can be directly and easily replaced (Gilbert et al., 1982). According to this view, if children's "alternative frameworks" exist, they are not strongly held and are easily replaced. For centuries teachers have held the "tabula rasa" or blank slate assumption. This approach assumes that prior to formal teaching the learner has no knowledge of a topic or that students arrive at the classroom door knowing nothing. Teaching is based on the assumption that the learner's "blank mind" can be filled with information supplied by the science teacher. Based on current knowledge related to instruction and learning, we know that the teacher dominance and blank slate assumptions are no longer correct (Clement, 1982).

Changing Children's Alternative Conceptual Frameworks in Science

Once a student's schema is known and alternative concepts identified, how can the alternative concept can be changed? Posner et al. (1982) have suggested four conditions needed for students to change their naive conception:

1. The student must be dissatisfied with the naive concept that he/she holds. The students must be aware of their ideas and be able to see the difference between their ideas and those of the scientific community.

2. A new concept must be intelligible. Students must be able to construct a representation, or mental model of the idea and understand what it means.

3. The new concept must be initially plausible. The concept must be potentially true and believable to the student. The new concept must be reconciled with their prior concepts.

4. If a student is going to incorporate a new conception into his or her schema at the expense of a very comfortable, long-held alternative framework, there has to be a convincing reason. Thus, the new conception has to be shown to be more useful than the old conception. If the new concept solves a previously unsolved problem, if it suggests new ideas, or if it gives better explanatory and predictive power than was previously possible, then the child would be more willing to accept the new concept.

Teaching for conceptual change requires the teacher to focus on the students' ideas, predictions and explanations for phenomena. An important element in promoting conceptual change is the establishment of a non-threatening environment which encourages the exchange of ideas between students and teacher. Teaching strategies which rely on oral discourse and analogies, metaphors, and physical demonstrations, seems most useful in altering students' naive conceptions (Vosniadou & Brewer, 1987). "Discrepant events" lessons are also used to contradict students' alternative frameworks, make them dissatisfied with their own explanations, and lead them to search for better ones (Mills, 1985). In addition, the concept of "accommodation" in Piaget's theory is commonly used to denote what happens in the student's mind as he modifies "alternative frameworks" to reach concensus with the accepted scientific conceptions (Piaget, 1964).

Perhaps the alternative frameworks which students hold should influence the science curriculum in terms of how it should be taught. A conceptual view of learning implies that the theories, facts, concepts, and principles are relevant to a student if they can be placed in a existing or new conceptual framework. Learning defined as conceptual change is learning in which students abandon alternative concepts and adopt more accepted scientific alternatives. Science teaching which allows children to retain their alternative frameworks is doomed to failure, for it will only produce additional misconceptions.

The Elementary Science Teacher

All science teachers want their students to learn and understand science. The science learned should be personally meaningful and should allow for successful participation. Why, then, do so many students simply memorize information and retain their naive concepts? Part of the answer might lie with the content background, teaching behaviors and alternative frameworks of science teachers. In many cases, teachers at the elementary level feel that their background or training is inadequate. Few teachers with an elementary major have taken many science courses. According to Weiss (1978), only 22 percent of the elementary teachers judge themselves adequately prepared to teach science. In contrast, 67 percent judge themselves adequately prepared to teach reading (Weiss, 1978). According to Weiss, by the time most future elementary teachers become students in junior high school, they (1) decided that science was a difficult subject which should be avoided, (2) took classes which were theoretical, detailed and had no application for science in the elementary school, (3) took science classes which included few labs, or (4) took science courses which emphasized a cookbook approach where completing all the steps and getting the correct product or answer was considered more important than the process used to understand the concept. In addition, these future teachers often found that their pre-university backgrounds in science were inadequate for success in regular arts and science classes at the college level. Science classes designed for teachers were less than challenging or interesting and failed to make science relevant or meaningful to everyday life (Flegg, 1981). If teachers feel they do not have an background for teaching science, they will not spend much time doing just that, "teaching science" (Flegg, 1981). Elementary teachers, like their students, are a product of the science education they have received. It is not surprising, therefore, that in today's society many elementary teachers do not understand much about science.

"Alternative frameworks" exist for many science concepts in the minds of pre-service and in-service teachers. Meaningful science lessons cannot be taught by teachers who themselves do not find scientific concepts meaningful or logical. A science concept may seem meaningful to the teacher but still be wrong. Science teachers at the elementary, junior high, and high schools levels and teacher education majors display similar alternative frameworks, it would appear that the problem of alternative frameworks is widespread (Trembath & Brarufaldi, 1981).

Obviously, the teachers' view of science is crucial as he/she interprets the elementary school science curriculum and relevant science concepts when preparing to teach. Having good elementary school science curriculum materials may or may not modify the teacher's view in the direction of a mature view of science. Needless to say, the teacher's mental schema for science concepts, combined with children's search for science concepts, will have profound implications on the learning outcomes. It is hoped that the science presented to children would be close to scientists' view of science (Gilbert et al., 1982). Unfortunately teachers usually approach science instruction in a manner similar to how they were taught. Teachers assume, as do many textbook writers, that basic science concepts can be introduced by simply demonstrating a few classical experiments in a simplified form (Nussbaum & Novick, 1982). This leaves students with the impression that the science curriculum is a large collection of ambiguously specific data to be memorized and sometimes manipulated. What is to be tested is usually factual material. Therefore, the common question from kindergarten through college, is "What do we have to know for the test?" rather than "What should we know for life?" If information is to be useful to the student it must be meaningful and relevant to the students' lives. John Dewey talks about relevancy in 1938 when he asked:

> What avail is it to win prescribed amounts of information about geography and history, to win ability to read and write, if in the process the individual loses his own soul; loses his appreciation of things worthwhile, of the values to which these things are relative; if he loses desire to apply what he has learned and, above all, loses the ability to extract meaning from his future experiences as they occur (p. 49)?

Unfortunately, even if teachers are well prepared in their content area we cannot assume that they will be effective teachers. Teachers must also use effective teaching behaviors. A teacher may not be able to verbalize his/her philosophy of education but can demonstrate it every day in the way in which she treats students or teaches a lesson (Berliner, 1986). Much of the research has now shifted from "What are effective teacher behaviors," to "What are the knowledge and beliefs that underlie the effective teaching behaviors" (Berliner, 1986).

Tasker 's (1981) research suggested that it is no surprise that science instruction has not been as effective as we thought. Through observation of science classrooms, he found the following:

1. The pupil considered each lesson an isolated event, although teachers assume that students are connecting information from previous lessons with the new lesson being presented.

2. The purpose the teacher has for the lesson and the purpose the student has for the lesson might be significantly different.

3. The investigations and demonstrations considered important by the teacher and textbook are not considered important or of interest to the students.

4. Students were assumed to have certain knowledge structures by the teacher. Frequently, however, through observation, it could be seen that structures the students had and the one the teacher had were not compatible.

5. Teachers assumed students would have a different understanding of the outcomes of an experiment than the student actually developed.

Tasker (1981) also found that in situations where pupils were involved in teacher or textbook guided investigations, pupils spent much of their time making executive type decisions such as, "What do we do now?" "What instruction are we up to?" and very little time thinking about scientific concepts. This may well be encouraged by typical assessment procedures which tend to reward well-written laboratory accounts and the production of appropriate statements and equations in essays and tests rather than requiring pupils to really think about how and why things behave as they do.

Whitehead (1929) challenged educators by asking, "how in our system of education we are to guard against . . . mental dryrot." He answered, "We enunciate two educational commandments. Do not teach too many subjects, and again, what you teach, teach thoroughly" (p. 17). Although spoken 60 years ago, Whitehead's conclusion is true today. These two educational commandments are most certainly being broken in our schools today. Despite the recommendations given for "good" pedagogy (teaching less, going more slowly, and learning more deeply), you can enter many classrooms and see an abundance of facts, formulas, procedures, lists, and dates. For example, introductory biology classes teach the names of all the central branches of the plant and animal kingdoms. Chemistry labors through the periodic table of the elements. English covers the plots of stories and plays of major writers. Mathematics covers the basic procedures of algebra and geometry. History goes from the pharaohs to the latest election. Very few people could retain all these facts.

Jerome Bruner (1960) outlined the objective for effective lessons by stating: "The first object of any act of learning, over and beyond the pleasure it may give, is that it should serve us in the future. Learning should not only take us somewhere; it should allow us later to go further more easily." We can all be informed, but it is up to each one of us to understand. To understand facts is to have used them. As an ancient Chinese saying put it, "I hear and I forget, I see and I remember, I do and I understand."

Why does such ineffective teaching persist? One reason is that disseminating/ telling information takes only a fraction of the time it takes to put information to use. Because of the concern that is being focused on education, testing has been given a new emphasis and as a result, teachers more than ever before feel that spending quality time on a chapter is a waste of time. They spend more time informing and preparing for tests and less on the process of creating individual understanding. Testing drives schools, and as a result teachers teach in the way that will best facilitate children passing the tests.

Ideally, educators need to be made more aware of students' particular "alternative frameworks." This requires that the teacher must have the skill needed to identify them. Additionally, when the teacher does discover something is mistaken in the student's idea about a lesson, the teacher should not attribute this to the student "not understanding the lesson." The problem may be that the student understands differently from what was intended (Nussbaum & Novick, 1982, p. 184). If teachers recognize students' alternative frameworks, they can be used as springboards for positive conceptual change. If instructional material includes information about possible student alternative frameworks, teacher intervention can improve science teaching and, therefore, children's understanding of science.

Research on Children's Alternative Frameworks

During the 1970's and 1980's there was an increase in research activity concerning children's conceptions of a wide range of scientific phenomena. A review of these studies reveals a common theme which involves the attempt to discover the science concepts children hold and the degree to which these views are congruent with those of scientists.

Erickson (1979) studied patterns of children's beliefs about heat and temperature. From informal interviews with children ranging in age from 6 to 13 he reported that the children mentioned the existence of cold as an opposite to heat. Like heat, cold is endowed with a material property as it is transferred from ice cubes to the water to explain why the temperature of the water decreases when an ice cube was added. When ice was melted many children frequently expressed belief that soft things melt more easily than hard things. When asked why a large ice cube takes longer to melt than a smaller ice cube, they said the larger ice cube had a colder temperature than the smaller ice cube. The interesting conception expressed in this idea was that the temperature of a body is related to its size or the amount of "stuff" present, i.e., temperature was confused with quantity of heat. The larger the animal the higher the temperature. When probing for a deeper understanding of what the children knew, the interviewer found that the children thought heat was a substance like air or steam, temperature was a measure of the mixture of heat and cold inside an object, and all objects contained a mixture of heat and cold. Erickson concluded overall that these three ideas center around the very pervasive belief that heat and cold are a type of substance like air which is capable of flowing into or out of objects. Younger children would claim that the temperature of water in a jar would be lowered when some of the water was poured out.

Biddulph (1983) also interviewed young children to identify the ideas they had about floating and sinking in water. He used "interviews-about-instances" cards which depicted ten objects (e.g., metal paper clip, short length of candle, school rubber eraser) that either floated or sank to explore children's explanations of why they floated or sank. Data were also collected from classroom surveys and from lessons designed to elicit student questions and answers about the topic. The interviews revealed that children attached different meanings to "floating" which varied with context and that these meanings in some cases differed from those of scientists. For example, 33 of the 104 children who looked at the card depicting a spider standing on the surface of the water considered that the spider was not floating. The most common reason given was that it was entirely on top of the water, perhaps being held up by the water's skin. Older children often suggested that the spider was floating. While adults tend to think something is either floating or sinking, many children had a third category believing that part of an object can be sinking and part floating. Of 104 children interviewed, 18 spontaneously used this third type of categorization on 23 occasions.

A study designed by Porter (1974) used a body outline drawing to study elementary school children's perceptions of internal bodily structures. The purpose of this study was to determine how perceptions of body structure and functions change with increasing age. Porter assessed the children's perceptions by looking at: (1) what organs were frequently drawn and with what degree of accuracy, (2) sex differences illustrated, (3) what body systems children were most familiar with, and (4) what unusual parts they drew and named. Results showed that the children knew considerably more about their internal body parts than previous studies had indicated. The parts most frequently named by all children were the heart (99%), brain (92%), and bones (90%). Many children colored their drawings or made solid areas to show that blood was everywhere inside the skin. Blood, when mentioned, was rarely associated with the veins or blood vessels except by some older children. The three body systems most frequently represented were the cardiovascular, gastrointestinal, and musculoskeletal. An interesting observation was that 142 subjects out of 144 drew the heart. Of these, 103 or 73.5 percent drew a valentine heart, although the subjects were instructed to draw a circle where the heart was located. Of the 87 children who drew a stomach, 64, or 73.5 percent, drew more than half of the stomach below the level of the navel. Only four of the 144 children mentioned the reproductive organs. Of the four, three were fifth graders. At every age level boys named more parts than girls. Porter concluded that children do know a considerable amount about internal parts of their bodies.

A more specific investigation was conducted by Arnaudin and Mintzes (1986) to investigate children's alternative conceptual frameworks of the cardiovascular system. Two-hundred fifth and eighth grade children were asked to tell about the functions of the blood, the path taken by blood as it passes through the body, and what happens to blood after it reaches the cells. Almost two-thirds of the fifth graders subscribed to the notion that blood is simply a red liquid, but only about 20 percent of the junior high students opted for this answer. The overwhelming majority (84%) of fifth graders gave nonmechanistic answers, ones that showed they knew of blood's importance to life but did not understand how blood actually functioned to maintain life. Forty percent of elementary school children chose a three-chambered (amphibian) heart. About 15 percent of all the students chose the four-chambered (human) heart or the two-chambered (fish) heart. Eighth graders chose the three-chambered and four-chambered hearts in about equal proportions (30%). However, over 20 percent of these eighth graders selected a solid heart with tubes. A large proportion of students in both groups (70%) correctly suggested that the heart pumps blood. However, a significant number ascribed additional functions to the heart, like cleaning, filtering, making blood, and storing blood. The picture selected by the largest number of children (about 30%) at both grade levels was one in which a circular pathway makes its way from the heart to a target organ and back. Approximately 20 percent of the children the earth? The world's water supply in all forms (liquid, vapor, and ice) is tremendous. If this subscribed to the notion of a completely open system with the blood unconfined by vessels. The study convinced the researchers of the importance of eliciting from children what they really think about a subject. Teachers at every level must begin listening to students ideas, reporting the results they obtain, and planning future lessons accordingly (Arnaudin & Mintzes, 1986).

Concepts of light held by nine to 16-year old students were identified and described by Stead and Osborne (1980). The main concept examined was the transmission of light. The method of obtaining data in Stead and Osborne's investigation was an "interview-about-instances" procedure. Students were shown drawings on cards which represented instances of sources of light (i.e., candle, sun, torch, television, heater) and reflectors of light (the moon, painting, mirror, movie screen, rainbow). The results revealed that students in the study did not see light as traveling from a source, especially during the day. The children thought an object emitted light at night, and that the object was the light source. In addition most students saw the light traveling further at night.

Following their study of children's concepts of light, Stead and Osborne (1981), investigated children's ideas about friction. A deck of 10 cards was used in the interview-about-instances method to provide a focus for discussion about the idea of friction. A total of 38 pupils ranging from 7 to 11 years of age were interviewed individually. It was found that many children (even those who had taken a physics course) have non-scientific views about friction. Some pupils had a reasonably sound scientific view of friction as a force and could make that explicit. All the subjects understood that friction was associated with movement. Twelve pupils considered that friction was associated with the rubbing together of only solid objects while others considered friction could occur with liquids. In the author's opinion, these non-scientific views held by children are not isolated misconceptions but are firm, consistent, and coherent alternative frameworks.

The particulate nature of matter was investigated by Novick and Nussbaum (1981) using a paper-and-pencil instrument. A total of 576 students in grades 5-12 were used in the study.

Subjects were asked to (a) complete a drawing, (b) write an explanation (free response), or (c) choose among a number of given explanations or drawings (forced choice) to respond to three questions dealing with gas particles uniformly distributed in a closed system. There was general increase over grade levels in the percentage of subjects favoring a uniform particle distribution. Most subjects at the junior high level and beyond retained a homogeneous distribution picture of gas particles in a container, even after evacuation of some of the air. Misconceptions which were revealed were that if gas is taken out of the container, the remaining gas is either at the top of the container or the bottom. Subjects in this group apparently pictured the evacuation process as analogous to removing liquid from a filled container. This view was predominant in the elementary school sample. Subjects were asked to choose among several explanations for the fact that particles of gas in a closed flask do not fall to the bottom. The percentage of subjects attributing uniform particle distribution to inherent particle motion increased with age. Subjects were asked to explain how cooling a gas until it liquefies affects the gas particles. Relative to descriptions of the air in the evacuated flask, 30-40 percent retained a uniform particle picture in the flask-balloon system containing heated air. Far fewer subjects explained cooling in terms of decreased particle motion or energy. The response which explained cooling in terms of decreased particle motion peaked at around 25 percent at the senior high level and drops to just 15 percent at the university level. Subjects were also asked to explain how heating affects gas particles. The percentage of subjects viewing heating in terms of increasing particle motion was larger than the percentage viewing cooling in terms of decreasing particle motion. In one question pupils were asked to choose among a number of responses to the question, "What is there between the particles as drawn in the evacuated flask?" There was a reluctance by students to think of the space between particles as completely empty. Of the elementary and junior high levels only 20 percent thought the space between the particles was completely empty. Of the high school student's and above 37 percent thought the space between particles to be completely empty. Beyond junior high 60 percent of the subjects did not picture empty space between particles in a gaseous medium. The results from this study supported the idea that pupils differentially internalize aspects of a scientific model. From cross-age comparisons it appeared that cognitive difficulties raised by certain aspects are real and not overcome by many older subjects.

A study to determine intermediate and junior high school students' concepts of living and non-living things was conducted by Tamirc, Gal-Choppin, and Nussinovitz (1981). The subjects (N=424) were chosen from 17 schools in big cities, small towns, and villages all over the country of Israel. Distribution was as follows: grades three to four, N=70; five to six, N=220; and seven to nine, N=104. The students were given a classification test composed of 16 pictures, 8 of living creatures and 8 of inanimate objects. Questions were then asked about the pictures of the following creatures: three adult animals (cat, butterfly, and fish); three adult plants (tree, herbaceous plants, mushroom), and two embryos (seed and egg). All subjects were able to correctly identify the three animals. The tree and mushroom were considered alive less often than inanimate objects like a river or the sun. Eggs were not considered as being alive by half of the subjects, compared with 40 percent who classified seeds as not alive.

Working with older university students Caramazza and his associates (1981) asked university students to solve simple problems about the trajectories of falling objects. Fifty undergraduate students at the Johns Hopkins University served as subjects. They were instructed to consider a ball and string depicted in line drawings as moving in an arc as a pendulum. The strings were cut when the ball was in the location indicated and moving in the direction indicated in the line drawings. Only 25 percent of the subjects produced responses that demonstrated a basic understanding of projectile motion. The remaining 75 percent revealed a variety of gross alternative concepts. Three subjects believed that the ball would fall straight to the ground; five subjects believed that when the string was cut, the ball fell in a direction opposite to that of the force exerted by the string; other students believed that when the string was cut, the ball would continue for a short time along its original arc and then fall directly to the ground. To the researchers it appeared that the students developed beliefs about motion on the basis of their perceived experience (autonomous) and tried to apply this experience to the problem.

Fenderson (1983) used a structured interview and survey design to investigate elementary children's notions of earth. In this study, she compared children in Oklahoma schools to those in California, Nepal, and Israel. Fenderson found that children in Oklahoma held generally the same notions of earth as did children in the other studies. However, it was found that students in the Oklahoma sample held more complex mental schema than the children in the other studies. Because she was interested in how the home environment influenced what the children were thinking she developed a parent survey. The general findings of this study were that children of all age levels were able to verbalize facts about the earth's shape, position and gravity; however, upon further probing many showed mixed understanding and commitment to these verbalizations. The results of the study also indicated that there was a degree of readiness for earth notion subject matter as early as kindergarten. Children develop basic mental schema at a young age, and these may be carried into adulthood where decision making is influenced.

The understanding of biology concepts was studied by Marek (1986). The subjects included in the study were tenth grade biology students attending an urban high school in Oklahoma. In a paper and pencil test, the students were asked questions about the cell and the process of diffusion. In the study only 15.8 percent of the students demonstrated complete understanding of a cell, and only 1.8 percent demonstrated a complete understanding of the diffusion concept. A partial understanding of the cell and diffusion concepts was demonstrated by 28.1 percent and 35.7 percent of the students, respectively.

Only a few research studies have been conducted in the area of children's concepts of the water cycle and are of particular value to the study being conducted by the author. Cosgrove and Osborne (1981) investigated children's views of physical change associated with boiling, melting, dissolving, evaporating, and condensing. The data were obtained using the "interview-about events" method in which students were asked to describe and then explain what happened during each of six events. Forty-three pupils ranging in age from 8 to 17 years were interviewed. One finding indicated that although students can often associate the appropriate technical term with a concept such as evaporation, many students have no scientific conceptual model to explain these terms. For example, pupils readily recognized when "condensation," "evaporation," or "melting" was occurring. However, when these children were further questioned their responses indicated that they had no mental model represented by these labels. Osborne and Cosgrove also found that scientific models which have been taught to pupils are taught in an abstract way and not related to everyday experiences.

Fifty kindergarten children were individually questioned to identify the extent of their understanding of selected physical phenomena. Phenomena to be investigated were selected from textbooks representative of widely used series published from 1955 through 1960. Listed below are some of the 16 phenomena which formed the basic framework of the investigation: (7) rain comes from clouds, (8) rain is water, (9) water may evaporate into air, (10) sun and wind speed evaporation, (11) water which evaporates may form clouds and rain, (12) water freezes into ice when it is cooled enough, and (13) ice melts and becomes water when it is warmed enough. All children were aware that rain is water. However, only 40 percent of the children seemed to realize that rain falls from clouds. About one-half realized that water could evaporate into air, although only a few used the term "evaporate." When water was in a less obvious situation, such as in wet clothing, explanations of drying implied considerably different understandings of evaporation. Nearly two-thirds could give no explanation for the source of water in clouds. Of the 38 children who did give explanations, over one-half stated that God or Jesus was responsible. Nearly three-fifths of the children understood that water freezes and becomes ice when it is cooled enough. Most children, 92 percent, explained that ice will melt at room temperature and become liquid water, but only 42 percent appeared to understand that heat was necessary to cause melting (Inbody, 1963).

Smith (1984) examined a common elementary science lesson on the water cycle, and investigated how this lesson might be misinterpreted by the student. The usual demonstration of the water cycle for children includes a tea kettle with boiling water, a pan of ice held over the escaping vapor, and the gradual collection of drops of water on the underside of the pan. For the child who is struggling to attend to the visual and auditory information of a demonstration, its not surprising that terms such as "evaporation," "condensation," and "precipitation" remain stored in what Larkin (1983) calls flashcard memory, unconnected bits of information that can be retrieved only when the context matches exactly. The tea kettle and pan of ice are close together, yet children are expected to map this distance onto actual spatial differences of thousands of feet, between a pond and a cloud. Teachers, in an attempt to help their students make sense of the demonstrations, use metaphors such as "water is held in the air like a container"; and "clouds absorb water like a sponge" which tend to confuse students further. Smith (1984), concluded that the lessons clearly overtaxed the abilities of young children to mentally represent the events demonstrated, to construct functional rules for those events, to coordinate rules into a dynamic model, and to manipulate the mental model to explain real life events. Perhaps the implication from this study is that instruction on the water cycle should be planned for older children whose working memory capacities can maintain and manipulate all the necessary factors.

Beveridge (1985) investigated children's views of evaporation. Ninety children, ages 5, 7, and 9 were asked to describe what happens to boiling water. The children responded to lessons about either the non-absorbent nature of a pan of water or the importance of the visible steam produced when water boils. Within each age group, children were found to develop alternative frameworks of evaporation which, with age, became more consistent with the adult scientific view.

Summary

Evidence from recent studies, Scholastic Aptitude Tests (SAT), poor achievement test scores, and low enrollment in elective science indicates that students are not learning basic science concepts well. Much of this failure to understand may be attributed to the lack of in-depth learning coupled with tenacious "alternative frameworks" which children hold that are inconsistent with accepted scientific answers. These "alternative frameworks" make sense to the student and are hard to displace. The discovery of children's "alternative frameworks" is challenging educators and theorists to rethink the role of prior knowledge in learning. Learning information is facilitated when a new concept is associated with an existing mental framework that is free of "misunderstandings." However, learning is hampered by existing alternative concepts of science which interfere with rather than enhance, learning. Studies of alternative concept formation reveal new specific ways to attack instructional problems in the teaching of science and enhance the development of science curriculum.

"Alternative frameworks" can be changed if 1) students are dissatisfied with the old concept, 2) the new concept is intelligible to the student, 3) the new concept is plausible, and 4) the new idea is more useful than the old idea. Educators must solve the problem of how to effectively confront "alternative frameworks" so that correct science concepts can be developed.

There is general agreement in the literature that the organization of information in memory is referred to as a schema, or existing conceptual framework. Previous experiences are stored as schema. Concepts are represented by words and symbols, however, students must have much deeper understanding of concepts than just the symbols which represent them. Part of this understanding requires a dynamic mental model of the event. In order to transfer learning to other disciplines and real life events, the student must posses dynamic generalizable mental models, not just the words.

A child's understanding of any concept, in general, and the concept of the water cycle, in particular, depends on the child's pre-school experiences, formal school experiences, and cognitive development. It is important that scientifically accepted concepts replace the child's "alternative concepts." When the "alternative concept" is identified, it can be displaced and further reinforcement of the "alternative concept" can be prevented so that future accommodation of a more formal concept will be less difficult. The relatively limited number of studies investigating children's understanding of water concepts suggested the need for additional research. The following concerns need further investigation.

1. There is a need to better understand the nature of children's notions about the water cycle.

2. Teachers need to be more aware of children's "alternative frameworks" and ways in which alternative concepts may be replaced.

3. There is a need to explain more fully the variables and experiential factors related to and affecting children's naive conceptions about the water cycle.

In summary, there is considerable evidence from recent research of the importance of the ideas that children bring with them to science lessons. While children frequently pass tests and other formal assessment hurdles, the research clearly suggests that children often do not really change their ideas of how and why things behave as they do as a consequence of science instruction. In today's world, students are overloaded with information, data, opinions, and experiences which can be accessed with the push of a button on their radios, computers, T.V. sets, and telephones. Because the population has increased tremendously, we are a "global village" on spaceship earth (Ferguson, 1987), and a more effective provider of great quantities of information than the world of our grandparents. Today, the educators' job is to be less a distributor of this great quantity of information and more of a helper to encourage students to appreciate and use experience and information in productive ways. Traditionally it has been assumed that prior knowledge will facilitate learning. However, if prior knowledge conflicts with new information, a smooth connecting of information may not occur.

It will be the purpose of this study to investigate the concepts children have concerning the water cycle, and what "alternative frameworks" they may hold. Suggestions will be made concerning ways to detect children's "alternative concepts" as well as ideas for further research.

CHAPTER III

DESIGN AND METHODOLOGY

Introduction

The primary purpose of this study was to identify, using a structured interview format, the water cycle concepts held by kindergarten, second, fourth, sixth, and eighth grade students. A secondary goal was to determine the relationships between water concept development and the following factors in the home and school environment: 1) score on the water cycle knowledge instrument, 2) cultural sources of information in the home, 3) school instructional time, 4) verbal ability, 5) child's cognitive development, 6) gender, age, elementary achievement test scores, and parent's level of education.

Development of the Interview Instrument

The water cycle interview instrument was developed to uncover children's concepts of the water cycle. This instrument was constructed by the author of this study after compiling instrument items and information from previous research. Many of the interview items were developed by examining previous studies which investigated children's alternative frameworks (Beveridge, 1985; Fenderson, 1983; Osborne & Cosgove, 1983) (Appendix G). Additional questions were written by the author as per suggestions given by five Oklahoma elementary school teachers. In addition, items were added upon advice of an expert group formed to establish content validity of the water cycle interview instrument.

Four other instruments were used to evaluate children's understanding of water cycle concepts, (1) spatial ability, (2) verbal abilities, (3) sources of information in the home about the water cycle, and (4) time spent on instruction about water cycle concepts in the classroom.

These instruments were used because of their success in other studies dealing with children's concepts of the water cycle. A list of these instruments and a brief description follows:

1. Spatial Ability (water level task) - This Piagetian task measured students spatial ability and was used to identify a child's cognitive level (Wodsworth, 1978) (Appendix D).

2. Verbal Ability (verbal opposites) - The verbal opposites test is a measure of a child's verbal ability which indicates a child's verbal I.Q. A word was read orally and the child was asked to respond with a word which meant the opposite. Verbal opposite raw scores were used in the statistical analysis (Appendix F).

3. Sources of Information in the Home Survey - This instrument, developed by Fenderson (1985), asked parents for information about such matters as travel, television, books and conversations with their children about concerning water cycle concepts (Appendix B).

4. Teacher Survey - This instrument was administered to teachers to determine the amount of time spent on instruction of earth concepts, as well as other science related experiences (Appendix E).

Content Validity

A rough draft of the water cycle interview instrument was sent to a panel of six experts. This panel consisted of Sandy Van Thiel, Instructor, John Brown University; Denver Spears, Principal of Lowery School (a K-8 rural school near Tahlequah, Oklahoma); Dan Reck, a fourth grade elementary school teacher in Skiatook, Oklahoma; Dr. Ted Mills, Professor of Science Education, Oklahoma State University; Robert Raze, Oklahoma State University graduate student and elementary school teacher in Tyler, Texas; and Louis White, a fifth and sixth grade science teacher in Tahlequah, Oklahoma. These individuals were asked to examine the instrument, consider the clarity and content validity of the items used to assess children's concepts of the water cycle, and make recommendations for improvement. Each of the six members returned the instrument with suggestions. These suggestions were addressed by adding or amending certain items on the interview instrument.

Subjects

Subjects for the study were selected from a rural Oklahoma public school located 38 miles from an urban center of 250,000 population. The school was selected because of its rural setting as well as the anticipated cooperation from the teachers, administrators, and parents. The 9.2 square mile school district has a population of approximately 2,700 people, 9.8 percent of whom are unemployed. The population is predominantly rural, and includes both Caucasians and Native Americans. Several small firms dealing in oil, cement, rock and gravel are located in the school district.

The school district operates the following campus units: one high school, grades 9-12, (162 students); one junior high, grades 7-8, (76 students); and one elementary school (two classes per grade), grades 1-6, (242 students). The pupil population has been stable during the past five years. The high school offers 48 credits and works very closely with the Central Area Vocational-Technical Center. Approximately 20 percent of this high school's graduates attend college.

Procedures

A pilot study was conducted in early March, 1987, with 40 students, 10 enrolled in each of the kindergarten, second, fourth, and sixth grades of the Skiatook, Oklahoma, public schools. All instruments used in this study were field tested with parents, teachers, and students. The purposes of the pilot study were to (1) determine the length of time required for the interview and to refine techniques for administering the interview, (2) determine if students understood the questions to be used, and (3) identify the appropriateness of the demonstrations used with some questions. As a result of the pilot study the following changes were made in the research procedures: (1) directions to students were clarified and elaborated, (2) a decision was made to record all student responses in writing and on tape, and (3) some questions were deleted.

During January of 1987, class rolls were obtained from the rural school where the study was to be conducted. Parental permission was obtained for the 111 students involved in the study (Appendix C). Due to small class size, an intact population was used from students enrolled in the kindergarten, second, fourth, and sixth grade classes. Twelve eighth grade students were selected by the eighth grade teachers. In the total group of 111 students there were 25 kindergarten students; 29 second grade students; 22 fourth grade students; 23 sixth grade students; and 12 eighth grade students. Because of time constraints eighth grade students were only given the Water Cycle Interview. Clinical interviews were conducted in a room set aside for this purpose in the elementary school. These 30- to 45-minute interviews were individually administered by the researcher. The interviews were held during the months of April/May, 1987.

Responses were tape recorded and annotated in an interview booklet. Transcribed interview data were scored and analyzed by the researcher using a classification scheme developed by Shepard and Renner (1982), i.e., (1) No Response, (2) Specific Misunderstanding, (3) Partial Understanding, and (4) Complete Understanding. Complete and partial understanding responses were considered as being appropriate conceptual frameworks. A misunderstanding was considered to be an alternative conceptual framework. "No Response" by a child was considered to mean no conceptual framework (Figure 3). Demonstrations and questions were utilized for the interview to elicit children's explanations. Wherever possible, familiar materials, pictures, and real events were used along with the verbal questions to demonstrate specific concepts (Appendix A). For example, a wet spot on a paper towel was "evaporated" using a hair dryer. Other materials used included a ring stand, candle, small metal pan, peanut butter jar, a textbook showing pictures of clouds, a styrofoam ball, and liquid and solid water. Where it was not possible to recreate an actual water concept "event," pictures were used. The Water Cycle Interview (Appendix A) consisted of 30 questions. Each answer was given a score based on the following criteria: (1) Complete Understanding-three points (Appendix F, Van Theil, 1990); (2) Partial Understanding-two points; (3) Specific Misunderstanding-one point; and (4) No Response-zero. The maximum score possible was 90 points (Shepard & Renner, 1982).

Several guiding principles were followed throughout the interviews. These were based on research cited in the literature, the pilot study and the investigator's own experience with young children. They include:

1. To help reduce anxiety, each interview began with casual conversation about subjects of possible interest and concern to the child.

2. Questions were worded carefully to avoid influencing the child's response by giving him clues to the anticipated answers.

3. The interviewer attempted to be positive and to avoid communicating any anxiety of his own about the child's responses.

4. The interviewer made every effort to convey to the child a genuine acceptance of the child and any answers given. No answers given by the children were rejected as being wrong.

5. Interviews were conducted in a room which was quiet and free of distractions.

6. The interviewer attempted to adapt his behavior to the subject and the situation according to his evaluation of the motivations and defenses that might be influencing the child's responses.

Most questions were asked in a manner which would require explanatory answers rather than brief one-word, factual responses. Every attempt was made to get the child to explain his answer. The interview schedule was flexible and deviations were made to accommodate student schedules.

The water cycle interview was followed by the water level task which measured the student's spatial ability (Appendix G and Appendix D). Three separate drawings of identical empty bottles are presented to the child one at a time. The bottles are positioned vertically, horizontally, and diagonally. The child was asked to draw a line to show the surface of the water in each bottle so that it was half full. The child's cognitive level was assessed at Level One if the child drew the water line correctly when the bottle was held vertically. Level Two was given to responses that indicated the correct water line for the bottle held vertically and horizontally, and Level Three for responses when the bottle was held vertically, horizontally, and diagonally. If the child did not identify any of these positions a score of zero was given. This assessment was used to identify the child's level of cognitive development (Appendix G, Fenderson, 1983).

A verbal opposites task was used to measure each subject's verbal ability. Teachers from grades K, 2, 4, and 6 administered the verbal opposites task to the whole class a day after the water cycle interview. Each word was read orally by the teacher and the child was asked to respond with a word meaning the opposite. The verbal opposites task was scored by the author. A value of one point was given for each correct response. Colloquial terms or slang words in current use were scored as correct. The maximum score for this test was 96 points (Appendix F).

After the interview data were collected, a survey was sent to parents to collect information about activities, and/or television programs in the home about the water cycle. A self-addressed stamped envelope was included for easy return to the researcher (Appendix B). At the same time the home surveys were being sent, teachers were also given surveys to identify the amount of time spent teaching water cycle concepts in the classroom. Instructional time for each teacher was calculated separately for each grade level (Appendix E).

Data Analysis

The study used a basic design in which the dependent variable (water cycle score) was compared to the independent variables of age, grade level, elementary achievement scores, verbal ability scores (measures cognitive level), instructional time for water concepts by teachers, and water level task scores (measures spatial ability).

Pearsons product-moment coefficient of correlation were calculated for hypotheses 1-5. These correlations were used to describe the relationships between the dependent variable (water cycle score) and the following independent variables: (1) grade level, (2) sources of information in the home, (3) instructional time, (4) verbal ability score, and (5) water level task score.

Hypothesis number six was analyzed using stepwise regression with Water Cycle Score as the dependent variable, and (1) gender, (2) age, (3) elementary achievement scores, and (4) parent's years of education from the sources of information survey as the independent variables.

Mean scores by grade for all dependent variables for each grade were calculated separately. Statistical significance in all tests was predetermined and rejection set at the 0.05 level of confidence.

CHAPTER IV

RESULTS

Presentation of Data

The primary purpose of this study was to identify, using a structured interview format, the water cycle concepts held by kindergarten, second, fourth, sixth, and eighth grade students. A secondary goal was to determine the relationships between water concept development and the following factors in the home and school environment: 1) score on the water cycle knowledge instrument, 2) grade, 3) cultural sources of information in the home, 4) school instructional time, 5) verbal ability, 6) child's cognitive development, and 7) gender, age, elementary achievement test scores, and parent's level of education. This chapter presents the findings generated and a brief summary.

Statistical Data

Each of the questions to be answered is listed followed by a summary of the results.

Research Question 1 and Ho-1

1. Is there a relationship between grade level and water cycle knowledge attained by the child?

Ho-1. There is no significant relationship between grade level and water cycle score.

Results. A Pearson r correlation showed a tendency for knowledge of water cycle concepts to increase with grade level .662 ($t=.195$, $df=97$, $p<.01$) therefore allowing for the rejection of the null hypothesis.

TABLE I

MEAN VALUES BY GRADE FOR SEVEN VARIABLES

GRADE	VARIABLE	N	MEAN	RANGE
K	Achievement	25	149.900	102-105
	Verbal I.Q.	--	-------	-------
	Years of education:			
	a. Mother	7	13.286	12-16
	b. Father	7	13.286	12-16
	Water cycle score	25	24.840	11.0-40.
	Spatial score	--	------	-------
	Age	25	6.136	5.100-7.40
2	Achievement	29	256.793	188.-327.
	Verbal I.Q.	29	30.966	10.0-51.0
	Years of education:			
	a. Mother	12	12.250	11.00-14.00
	b. Father	12	12.167	6.000-16.0
	Water cycle score	29	32.724	23.0-46.0
	Spatial score	29	2.138	0.000-3.000
	Age	29	8.232	7.100-9.600
4	Achievement	22	375.818	217.0-478.0
	Verbal I.Q.	22	44.864	27.0-58.0
	Years of education:			
	a. Mother	16	12.438	8.0-16.0
	b. Father	16	12.00	6.0-16.0
	Water cycle score	22	44.364	30.0-66.0
	Spatial Score	22	1.955	0.0-3.0
	Age	22	10.273	9.10-11.90
6	Achievement	23	349.043	164.0-470.0
	Verbal I.Q.	23	53.739	30.0-66.0
	Years of education:			
	a. Mother	12	12.333	12.0-14.0
	b. Father	12	12.167	8.0-16.0
	Water cycle score	23	43.087	23.0-68.0
	Spatial score	23	2.087	1.0-3.0
	Age	23	11.996	11.10-13.10
*8	Water cycle score	12	43.18	22.0-67.0

*Eighth grade students participated only in the water cycle interview.

Research Question 2 and Ho-2

2. What sources of information in the home relate to the child's concept of the water cycle?

Ho-2. Sources of information in the home are not significantly related to children's water cycle score.

Results. A questionnaire was sent to the parents of the children involved in this study to see if some of the activities in the home were related to the score that was attained on the interview questions. The Pearson correlation between information in the home and children's water cycle score was .252 ($t=.325$, $df=37$, $p>.05$), therefore the null hypothesis was not rejected (Home Questionnaire in Appendix B).

Research Question 3 and Ho-3

3. Is the amount of school instructional time spent on the study of water related to water cycle scores?

Ho-3. The number of hours of school instructional time spent on water cycle concepts is not significantly related to water cycle score.

Results. Teachers were asked to indicate the amount of instructional time spent on teaching water cycle concepts (Table II). The questionnaire was prepared to determine if time spent teaching the water cycle was significantly related to water cycle scores. The kindergarten teacher reported spending less time on water cycle concepts than at any other grade level. The two second grade teachers indicated they spent 60 minutes teaching water cycle concepts. Both sixth grade teachers spent 60 minutes on water cycle concepts. The fourth grade teachers spent the most time on water cycle concepts; one teacher 90 minutes, the other 120 minutes. The

Pearson correlation between instructional time and water cycle score was .416 (t=.195, df=97, p<.01), therefore the amount of instructional time seems to be related to the water cycle score (Appendix E).

TABLE II

INSTRUCTIONAL TIME SPENT ON WATER CONCEPTS BY TEACHERS

Grade Level	Minutes of Instructional Time
K	20
K	20
2	60
2	60
4	120
4	90
6	60
6	60

Research Question 4 and Ho-4

4. Is there a relationship between mean verbal ability and water cycle knowledge?

Ho-4. The relationship between verbal ability and water cycle scores is not significant.

Results. Verbal ability, as measured by the verbal opposites task (Appendix F), for students in each grade except kindergarten in the study is shown in mean raw scores in Table I. The Pearson correlation between water cycle score and verbal ability was .517 (t= .232, df=72, p=.01), therefore, the null hypothesis must be rejected.

Research Question 5 and Ho-5

5. Is there a relationship between the child's cognitive development and water cycle knowledge?

Ho-5. There is no significant relationship between cognitive development and water cycle scores.

Results. The cognitive level of the child was measured by the water level task, which is the ability to shift spatial reference frames (Appendix D). Cognitive level was found to have a significantly related relationship to water cycle scores. The Pearson correlation between ability to shift spatial reference systems and water cycle score was .254 ($t=.232$, $df=72$, $p<.05$), therefore allowing for the rejection of the null hypothesis. The means for these variables are listed in Table I. Students who scored higher on the water level task (a measure of the ability to shift spatial reference frames), which is an indication of cognitive level, also scored higher on the water cycle interview.

Research Question 6 and Ho-6

6. Is there a relationship between the Water Cycle Interview score and the gender, age, elementary achievement test scores, or parent's level of education?

Ho-6. There is no significant relationship between water cycle interview scores and age, gender, elementary achievement scores, and parent's level of education.

Results. A step wise regression was used to identify variables which were significantly related to the water cycle score as $F(6,40)=7.526$, $p<.01$ (Table III). This suggested there was a significant difference between at least one set of means. It was found that achievement $p<(.001)$ as was measured by the Metropolitan Achievement Test, and gender $p<(.05)$ were the only variables which were significantly related to the water cycle score. Boys scored better than girls on the water cycle interview.

TABLE III

STEP WISE REGRESSION OF VARIABLES CONTRIBUTING TO WATER CYCLE SCORE

Mul R=.72		SQ M-R=.530	SEE 8.073	
VAR	Coff	Sd.	t	p
Constant	3.808	0.000	-.215	.831
Age	0.470	0.092	.267	.791
Achievement	0.060	0.581	3.656	.001
Gender	5.267	0.240	2.184	.035
Mother's Ed.	1.578	0.194	1.624	.112
Father's Ed	-0.430	-0.086	-.727	.471

Descriptive Data

The Water Cycle Assessment Instrument was developed to determine student's understandings of concepts related to the water cycle. The Water Cycle Interview Instrument explored children's concepts of the water cycle using standards developed by Van Theil (Appendix G). Tables IV-XXXVIII represent the percent of responses falling into each of the categories: full understanding, partial understanding, specific misunderstanding, and no response. The following questions guided this portion of the study:

Research Question 7

7. What types of conceptual frameworks have children developed for the concepts involved in the water cycle?

Research Question 8

8. What percentage of pupils function at each of the sub units of the water cycle interview responses?

    a. Full Understanding

    b. Partial Understanding

c. Specific Misconception

d. No Response

The specific concepts that were examined through the Water Cycle Interview Instrument were (1) Water/Land Ratio, (2) Groundwater, (3) Change of State, (4) Clouds, (5) Water Treatment, and (6) Rain. The following descriptive section describes how children answered research questions 7 and 8.

Water/Land Ratio

Question 16, (Table IV) asked the children, "Is more of the earth's surface covered by water or land?" Only 31 percent of the sample knew the earth was covered by more water than land. However this question had the highest percent of full understandings. A follow-up question was asked, "How do you know?" to insure children were not guessing. Usually children responded they had seen water on globes, in an atlas, the teacher told them, they had seen it in a textbook, or had watched some educational television program. Sixth grade students had the highest percentage of full understanding with 70 percent responding with full understandings.

TABLE IV

RESPONSES BY PERCENTAGE TO QUESTION 16
"IS MORE OF THE EARTH'S SURFACE
COVERED BY LAND OR WATER?"

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	24%	72%	04%
2	14	41	45	00
4	41	36	14	09
6	70	22	04	04
8	29	31	35	04
Average	31	31	34	04

<u>Groundwater</u>

Questions 20, 21, and 28 dealt with the concept groundwater. Question 20, (Table V) asked the question "What is a well?" Twenty-eight percent of the students had a full understanding of this concept. Many students were unable to provide a description of a well. It was surprising that this question did not elicit a higher percent of full understanding considering that these children were from a "rural" community where most families used well water. Fourth graders (44%) had the highest level of full understanding.

TABLE V

RESPONSES BY PERCENTAGE TO QUESTION 20
"WHAT IS A WELL?"

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	24%	16%	60%
2	00	69	21	10
4	44	45	11	00
6	35	48	13	04
8	<u>27</u>	<u>38</u>	<u>13</u>	<u>22</u>
Average	28	38	13	21

A follow-up to Question 20 (Table VI) read, "Can you drink from any well?" Twenty-one percent of all students had a full understanding of this concept. Twenty-nine percent had specific misunderstandings about drinking from "any well."

TABLE VI

RESPONSES BY PERCENTAGE TO QUESTION 21
"CAN YOU DRINK FROM ANY WELL?"

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	20%	08%	72%
2	10	28	41	21
4	06	31	63	00
6	02	47	47	04
8	20	24	29	26
Average	21	24	29	26

Question 28, (Table VII) asked the children to explain the word "groundwater." Fourth graders had the highest percentage (14%), of full understanding responses. Over one-half of the children gave responses which indicated that they did not know what groundwater was. Kindergarten children had the highest percentage of No Response (76%), followed by eighth grade students with 60 percent. The question asking the children to define what groundwater was had the highest percentage (60%) of no response (Table VII). Fourth graders had the highest percentage of full understanding on all questions related to groundwater.

TABLE VII

RESPONSES BY PERCENTAGE TO QUESTION 28
CONCEPT: GROUNDWATER

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	04%	20%	76%
2	00	14	21	66
4	14	09	05	59
6	04	30	26	39
8	09	10	20	60
Average	05	13	18	60

On all questions involving groundwater most students (35%) had no response (Table VIII).

TABLE VIII

AVERAGE PERCENT FOR ALL QUESTIONS INVOLVING THE CONCEPT GROUNDWATER

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
All Grades	18%	25%	20%	35%

Change of State

The questions related to change of state were numbered 23, 14, 15, 25, 1, 26, 29, 27, 30, 3, 4, and 22. These questions included such concepts such as water vapor, condensation, evaporation, melting, steam, and boiling.

Question 23, (Table IX) dealt with the concept of condensation. Children were asked to define the word condensation. None of the students K-2-4-6-8 had a full understanding of condensation, and only 1 percent of all students had a partial understanding. Ninety-three percent of all students gave "no response," the highest being in kindergarten. Five percent of all students responded with a specific misunderstanding.

TABLE IX

RESPONSES BY PERCENTAGE TO QUESTION 23
CONCEPT: CONDENSATION

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	00%	04%	98%
2	00	00	07	97
4	00	06	00	94
6	00	05	00	95
8	00	00	18	83
Average	00	02	05	93

The responses to Question 14 (Table X), also suggested that students had little understanding of the concept of condensation. Students were unable to provide an acceptable scientific model for how water condenses. A peanut butter jar was filled with ice and water, the lid tightly sealed, and the jar removed from view. After a time the jar was retrieved and the children were asked, "From where has the water on the outside of the jar come?" The responses of the 111 students indicate that 45 percent had specific misunderstandings. Sixth graders had the highest percentage of specific misunderstandings. No student from any grade used the term condensation with full understanding.

TABLE X

RESPONSES BY PERCENTAGE TO QUESTION 14
"FROM WHERE HAS THE WATER ON THE
OUTSIDE OF THE JAR COME?"

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	00%	00%	100%
2	00	00	48	52
4	00	04	59	37
6	00	00	62	38
8	00	08	59	33
Average	00	02	45	52

Because there seems to be a developmental sequence in the students' specific misunderstanding of the condensation process, the following student responses are given.

The majority of kindergarten children thought the water from inside the jar leaked from around the rim of the lid. Other kindergarten children thought the water came through the glass jar. Other responses from the kindergarten children included: "The water soaks through the glass," "rain," "from a freezer," "from the ice," "it gets real cold and some of the water comes through," and "leaking from the bottom of the jar."

Second graders had similar misunderstandings about condensation. The majority of the children in the second grade also thought the water leaked from the lid, or came through the side of the jar. Other comments were: "rotates out of the jar from the lid," "from the inside of the jar the water vibrates from the lid," "the water evaporates inside the jar to the outside by going through the glass," and "from the ice, it just melts."

The fourth grade students answers differed from kindergarten and second; their answers tended to be more elaborate and indicated a developmental shift of ideas. Several of their answers focused on temperature differences and described how the ice made the inside of the jar so cold that the water had to come out. Unlike the younger students, no fourth grader mentioned water coming from the lid. Some verbatim responses include: "from the moisture inside the jar," "the humidity makes it sweat," "the jar gets cold ice on the inside and when the ice melted the whatever you want to call it got on the outside of the jar from the melted ice," "maybe the water is just like steam," and "the water is real cool maybe it just freezes around the side and made the jar real wet."

Sixth graders had some of the same misunderstandings as the younger students, however, they were even more sophisticated. The word "evaporation" was used in several of their answers as follows: "It evaporated through the jar through the seams," "It comes through the glass because of evaporation because it gets hot," and "from wetness, it's ice evaporating." "It's kinda like fog, glass making dew on the outside of the jar." A large number of sixth graders mentioned that it was so cold inside of the jar that water formed on the outside. Sixth graders alluded to the theory that because of the differences in temperature on the inside and outside of the jar, water formed on the outside of the jar. These students knew there was a relationship between cold water on the inside of the jar and water forming on the outside of the jar. However after further questioning about how the water appeared on the outside of the jar, every sixth grader said, "from the water inside the jar." Although sixth graders had larger vocabularies their misunderstandings were similar to students in the previous grades.

Eighth graders seemed to have a less sophisticated understanding of condensation than did fourth or sixth graders. While no student in fourth or sixth grade mentioned water coming through the lid of the jar, two eighth graders reported this mis-understanding. Other eighth grade answers included "coldness on the inside of the jar," "pressure on the inside of the jar causes the water to go through the jar," and "the coldness attracts moisture." Two eighth graders also mentioned the water on the outside of the jar as "sweat." The students did not respond correctly to the question calling for a definition of condensation (Question 23). However, when presented with a concrete example, followed by an open-ended question (Question 14, Table X), eighth graders were more willing to attempt to answer the question.

In an effort to ascertain whether or not children understood the differences between evaporation and condensation, Question 15 (Table XI) specifically asked, "What is the difference between water forming on the outside of a cold glass jar and water disappearing into the air on a sunny day?" This question had the fourth greatest percentage (52%) of misunderstandings. The children could not describe the processes of condensation and evaporation, much less contrast and compare them. Kindergarten students had the highest percentage (84%) of specific misunderstandings, and fourth graders had the lowest percentage of specific misunderstandings (72%).

Of the kindergarten students, 16 percent gave "no response" to Question 15. Of those who did respond typical answers were: "It gets real hot in the mud puddle, then it's gone," "it's not outside," and "water in the jar can't go nowhere, water on the outside of the jar will fall."

TABLE XI

RESPONSES BY PERCENTAGE TO QUESTION 15 "WHAT IS THE DIFFERENCE ABOUT WATER FORMING ON THE OUTSIDE OF A COLD GLASS JAR, AND WATER DISAPPEARING FROM A PUDDLE INTO THE AIR ON A SUNNY DAY?"

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	00%	84%	16%
2	00	00	75	24
4	00	09	72	22
6	00	08	66	25
8	00	08	66	25
Average	00	04	78	20

Second graders (24%) also offered "no response" to Question 15. Of those who did respond, almost half discussed the cleanliness of the water. Examples of their responses were: "water in the jar is cleaner," "water in the jar is not dirty, the water in the puddle is," and "the water is clean, the jar is dirty." Other answers included "the sun shines on the water in the puddle, but not on the water in the jar," "the water in the jar is not disappearing," "the water in the puddle comes from ponds, and the water in the jar comes from a sink," "the water in the puddle vibrates to the ground," and "the water in the puddle is not disappearing."

Fourth grade answers were more involved than kindergarten or second grade answers. Eight students answered the difference between the puddle and the jar was that the sun shines on the puddle, but cannot shine on the water in the glass jar. Many students suggested evaporation occurs in the puddle, but not the jar. No mention of condensation was made. Two students reasoned that the water in the puddle lasted longer because the water in the jar was much colder. Another student responded "the water in the jar runs over, the puddle doesn't, it evaporates. The water in the jar sweats into water vapor. The humidity gets so hot it makes sweat come from inside of the jar." The students seemed to understand evaporation as the process of water disappearing, but could not understand condensation. For either evaporation or condensation students had no mental model, or schema in place to understand these concepts.

Most answers given by sixth graders used the word "evaporation." No sixth grader mentioned the word condensation. The majority of the sixth graders suggested the difference between water in the puddle and the water in the jar was that the sun shines on the puddle and the water evaporates. The sun does not shine on the jar and therefore it does not evaporate. The three answers offered most frequently by the eighth graders were: "the air tries to dry up the puddle," "The puddle soaks into the ground," and "heat evaporates, and cold forms sweat."

Students did not seem to understand that the water forming on the outside of the jar was the process of condensation and water disappearing from a puddle on a sunny day was the process of evaporation. Only 4 percent of the students gave a partial understanding and 20 percent did not respond. The responses to Questions 14, 15, and 23 implied that the children did not understand the concept of condensation.

Question 25 (Table XII), dealt with the concept of melting. Of 111 children, 73 percent had a partial understanding of this concept. All children generally described what they observed when something melted in responses such as: "when ice melts," and "like when ice cream melts." Second graders had the highest percentage (93%) of partial understandings, followed by eighth graders with 83 percent.

TABLE XII

RESPONSES BY PERCENTAGE TO QUESTION 25
CONCEPT: MELTING

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	56%	00%	48%
2	00	93	00	06
4	00	77	04	18
6	00	56	34	08
8	00	83	16	00
Average	00	73	10	18

Analysis of the responses to Questions 1 (Table XIII) and 26 (Table XIV), which deal with "boiling," revealed that no students at any grade level had a full understanding of these concepts. Where students had partial understanding, the answers were of low quality. Children could give examples of boiling but did not have an understanding of the changes in water when boiling occurred. For example, in Question 1, when shown a small pan of boiling water and asked what was happening to the water, the pupils would state, "It's boiling." No one could contribute an explanation of what was meant when they said, "it's boiling!" Pupil responses did not include the concept of "molecule," or indicate insight as to the particulate nature of matter. In addition, the concept that adding heat involves the increased motion of particles was not mentioned even with considerable prompting.

TABLE XIII

RESPONSES BY PERCENTAGE TO QUESTION 1 "I AM GOING TO LIGHT THIS CANDLE UNDER THIS PAN WHICH HAS WATER IN IT, WILL ANYTHING HAPPEN TO THE WATER?"

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	60%	36%	04%
2	00	65	17	17
4	00	81	18	00
6	00	86	13	00
8	00	66	33	00
Average	00	72	22	05

Question 26 (Table XIV) asked the children to define the word "boiling." Of kindergarten, second, fourth, sixth, and eighth graders, 69 percent had a partial understanding. Second and fourth graders had the highest percentages of partial understanding with 93 percent and 95 percent, respectively. Again partial understandings were composed of answers which noted only

physical observations that the children had made; for example, "when you put some water on the stove in a pot it boils," and "like when some water boils and bubbles appear." The children had a concept for the word boiling but lacked a mental model or schema to explain what actually happened when water boils (Table XIV). The children had no mental model for boiling, but could express observations of the real event.

TABLE XIV

RESPONSES BY PERCENTAGE TO QUESTION 26
CONCEPT: BOILING

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	52%	12%	36%
2	00	93	00	07
4	00	95	05	00
6	00	56	13	30
8	00	50	41	08
Average	00	69	10	17

More specific misunderstandings were encountered when the children were asked about steam, Question 29 (Table XV). Many students were not certain if steam and water vapor were the same or if they were different. Also, the difference between steam and smoke was not clear to some children. The students knew the words that stood for concepts, but did not appear to have a mental model for the concept.

TABLE XV

RESPONSES BY PERCENTAGE TO QUESTION 29 (STEAM)

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	36%	12%	52%
2	00	65	17	17
4	00	63	22	13
6	00	56	21	21
8	00	50	33	16
Average	00	55	20	25

Question 27 (Table XVI), asked students to explain the concept "freezing." Only 85 percent of the students had a partial understanding of this concept. Students did not exhibit a full understanding of the process of freezing, but described only what they had observed in the physical process. Common descriptions of the freezing process included "water gets real cold," "like when ice cream freezes," and "when you put something in the freezer, it freezes." Children did not mention molecules slowing down or speeding up, and/or the subtraction or addition of heat which constituted a full understanding. Fourth graders exhibited the highest percentage of partial understanding. Over three-fourths of the children understood that water will freeze and become ice when its cooled enough.

TABLE XVI

RESPONSES BY PERCENTAGE TO QUESTION 27
CONCEPT: FREEZING

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	76%	00%	24%
2	00	93	03	03
4	00	82	05	14
6	00	91	04	04
8	00	85	03	11
Average	00	85	03	11

Questions 2 (Table XVII), 3 (Table XVIII), 4 (Table XIX), and 22 (Table XX) are change of state questions dealing specifically with evaporation. For Question 2 (Table XVII) students were presented with a wet paper towel and a hair dryer and asked, "What will happen to the wet spot if I turn on the hair dryer?" Of the 111 students 35 percent had specific misunderstandings. A typical misunderstanding for younger children was, "the water goes into the hair dryer, or it just disappears." Fifty-seven of the students had a partial understanding and responded, "the water went into the air." Most fourth graders and sixth graders accounted for the disappearance of water by saying it evaporated. When asked to expand their understanding of the concept, they were unable to do so.

TABLE XVII

RESPONSES BY PERCENTAGE TO QUESTION 2 "I AM GOING TO PUT A WET SPOT ON THIS PAPER TOWEL, AND TURN THIS HAIR DRYER ON THE WET SPOT, WHAT WILL HAPPEN TO THE WET SPOT?"

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	0%	20%	64%	16%
2	0	55	37	06
4	0	72	22	04
6	0	82	17	00
8	0	66	25	08
Average	0	57	35	08

Most students (73%) had a partial understanding of Question 3 (Table XVIII), "What causes clothes to dry?" The typical answers were "sun" and "wind." None of the 111 students had a full understanding of how the sun or wind dried clothes; however, some younger children gave the impression they did not recognize the presence of water in wet clothes, they believed the clothes were just wet. These children seemed to think of water in more concrete terms, i.e., such as a glass of water or a pond. About 90 percent of the children indicated an awareness that wind can move objects and that it does so by blowing against them.

TABLE XVIII

RESPONSES BY PERCENTAGE TO QUESTION 3
"WHAT CAUSES CLOTHES TO DRY?"

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	92%	08%	00%
2	00	79	13	06
4	00	68	31	00
6	00	69	30	00
8	00	58	41	00
Average	00	73	22	02

Although students did have partial understandings of what causes the clothes to dry, they did not fully understand the follow-up questions to Question 3. Question 4 (Table XIX), "Where does the water go?" "Can you see it after it leaves the clothes?" "Can we still call it water?" and "Is it the same water?" elicited the greatest amount of specific misunderstandings. The majority of younger students (K-2) believed that the water soaked into the clothes, or dripped off on the ground. Most fourth and sixth graders, however, accounted for the disappearance of water by saying the water had evaporated. When asked to expand upon the concept, they were unable to so correctly. Of the older students (fourth, sixth, and eighth grades), a few also thought that the water soaked into the clothes. These students did not seem to understand that water vapor is still considered water.

TABLE XIX

RESPONSES BY PERCENTAGE TO QUESTION 4 "WHERE DOES THE WATER GO?" "CAN WE STILL CALL IT WATER?" "IS IT THE SAME WATER?"

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	0%	12%	68%	20%
2	0	12	58	10
4	0	59	40	00
6	0	56	30	13
8	00	41	58	00
Average	00	41	47	10

Question 22 (Table XX), asked the students to define the word "evaporation." Of the 111 pupils, only 34 percent could offer even a partially correct response. Answers consisted of "definitions" and examples of the word which indicated the children did not have a mental model "evaporation"; most older pupils accounted for the disappearance of water by saying the water had "evaporated," however, this was the extent of their explanation. Of the total group 43 percent of the students did not respond. Eighth graders seemed to understand more fully the above question concerning evaporation than the other grade levels. Out of the 12 eighth graders, 75 percent had a partial understanding. The students could give examples of evaporation but could not discuss the concept with any depth of understanding.

TABLE XX

RESPONSES BY PERCENTAGE TO QUESTION 22
CONCEPT: EVAPORATION

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	00%	08%	92%
2	00	03	24	72
4	00	63	36	00
6	00	60	30	08
8	00	75	08	16
Average	00	34	22	43

Tables XVII, XVIII, XIX, and XX are change of state questions, but deal specifically with evaporation. Analysis of the responses to these questions revealed that no students at any grade level had full understanding of the evaporation concept. Although over one-half of all students responded with a partial understanding, their answers were of poor quality. With the exception of Question 3 (Table XVIII), there was a trend toward greater understanding at the higher grade levels. When given a picture of clothes on a clothesline and asked, "What causes clothes to dry?" the older students exhibited less understanding and greater misunderstanding than their younger counterparts.

Students could not explain where water went after evaporation or how it got there. Question 22 (Table XX) had a greater number of no responses than any of the other questions dealing with evaporation. Children were aware that water disappeared, but not that it really went anyplace.

Question 30 (Table XXI), asked the students what the word water vapor meant to them. No student in the study had a full understanding of water vapor. The largest percentage (60%) of students had "No Response." Kindergarten and second graders had the highest percentage of "no responses." Partial understanding, misunderstandings and no response each increased with grade level.

TABLE XXI

RESPONSES BY PERCENTAGE TO QUESTION 30
CONCEPT: WATER VAPOR

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	04%	04%	92%
2	00	00	07	93
4	00	36	18	45
6	00	30	21	47
8	00	50	25	25
Average	00	20	13	60

Table XXI shows how students responded on all questions involving change of state. Questions involving change of state were better understood when a demonstration was presented. Students also tended to have more correct responses on questions about change of state events that were more familiar in their lives, i.e., freezing, melting. Analysis of the responses to these questions indicated that most students were familiar with the terms related to changes of state; they can give examples and often definitions of these terms. However, the answers clearly indicated that the students did not have a mental model of the concepts involved in change of state. Although they had a high partial understanding, they gave low quality answers which indicated an incomplete understanding of the concept. Children could give examples and definitions of each word but did not have an acceptable model of the processes involved in these changes. Students did not use such terms as molecules, or adding or subtraction of heat in their answers.

TABLE XXII

AVERAGE PERCENT FOR ALL QUESTIONS DEALING WITH CHANGE OF STATE

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
All Grades	00%	39%	28%	33%

Clouds

Questions 6, 8, 9, 10, and 11 dealt with the concept of clouds. Question 6 (Table XXIII) asked the question "How does water get into the clouds?" A higher percentage (41%) of second and kindergarten students (52%) held specific misconceptions. A partial understanding accounted for 31 percent of the responses to Question 6. However, the partial understandings were not very elaborate or detailed. A typical answer for a partial understanding from fourth, sixth, and eighth graders was: "water evaporates from lakes and goes up to the sky and forms clouds." Younger children, K-2, attributed water getting into the clouds by saying Jesus or God put it there. Thirty-four percent of the students gave no explanation for the source of water in clouds. However, fourth graders had the highest percent of partial understanding (90%).

TABLE XXIII

RESPONSES BY PERCENTAGE TO QUESTION 6
"HOW DOES WATER GET INTO THE CLOUDS?"

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	04%	52%	44%
2	00	13	41	44
4	00	90	10	00
6	00	34	25	41
8	00	34	25	41
Average	00	31	36	34

Question 8 (Table XXIV), "Where do clouds come from?" attempted to assess the student's understanding of the origin of clouds. Although misunderstandings seem to decrease with age, the data did not indicate that children understood the concept of where clouds originate. The low number of partial understandings and the high percentage of specific misunderstanding or no response suggested that the children did not understand this concept.

TABLE XXIV

RESPONSES BY PERCENTAGE TO QUESTION 8
"WHERE DO CLOUDS COME FROM?"

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	08%	76%	16%
2	00	13	37	51
4	00	36	36	27
6	00	26	30	43
8	00	41	25	33
Average	00	22	43	35

Question 9 (Table XXV) asked "How are clouds made?" Of all combined age groups, 64 percent did not respond to this question. Fourth grade students had the greatest percentage of no response (78%). One pattern did emerge, however, older children were more likely to exhibit partial understandings of the concept. Taken as a whole the data implied that students did not understand the concept of "how are clouds are made."

TABLE XXV

RESPONSES BY PERCENTAGE TO QUESTION 9
"HOW ARE CLOUDS MADE?"

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	00%	40%	60%
2	00	00	24	76
4	00	04	18	78
6	00	14	20	66
8	00	33	26	41
Average	00	10	27	64

Surprisingly, the responses to Question 10 (Figure XXVI), "What do you think clouds are made of," indicated no full understanding. Kindergarten students responded with the greatest amount of specific misunderstandings (60%); however, there was a large percentage of misunderstandings across all grade levels. Kindergarten, second, and fourth grade students gave similar answers such as clay, dust, rain, snow, cotton, air, gas and dust, steam, smoke, wool, water and wind, powder, and pepper and salt. Sixth grade answers were more verbal and sophisticated but were no more correct than students in the lower grades. Eighth graders used explanations not used by any other grade level. These students thought clouds were made of "atoms and fog," "dust, smog, and chemicals," "humidity and air," "water vapor and elements," and "magnetic something fills it up." Although older students' use of terminology was more elaborate, older students did not exhibit a better understanding of the concepts involved.

TABLE XVI

RESPONSES BY PERCENTAGE TO QUESTION 10
"WHAT DO YOU THINK CLOUDS ARE
MADE OF?"

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	04%	60%	36%
2	00	20	48	31
4	00	22	45	36
6	00	34	39	26
8	00	33	58	08
Average	00	23	50	27

Question 11 (Table 27), asked students to respond to "How do clouds get up in the sky?" From grades four to eight the number of students who did not respond to this question increased. Eighth graders had the highest percentage of "no responses" (66%). Specific misunderstandings decreased with age until the eighth grade level.

TABLE XXVII

RESPONSES BY PERCENTAGE TO QUESTION 11
"HOW DO CLOUDS GET INTO THE SKY?"

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	04%	60%	36%
2	00	04	48	48
4	00	31	31	38
6	00	30	22	48
8	00	00	34	66
Average	00	14	39	47

Overall, students had a low understanding of a concept for clouds. Students recalled words and fragments of concepts but were unable to connect clouds with other aspects of the water cycle. Especially lacking was the connection between the concepts of evaporation, condensation, and clouds. None of the students use the kinetic/molecular model to explain the formation of clouds. Of all grade levels, eighth grade students seemed to know less about clouds than any group. Table XXVIII shows how students responded on all questions involving clouds.

TABLE XXVIII

AVERAGE PERCENT FOR QUESTIONS INVOLVING THE CONCEPT OF CLOUDS

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
All Grades	0%	28%	34%	39%

Water Treatment

The three questions that dealt with water treatment were: Question 17 (Table XXIX), "Could we run out of good clean water?"; Question 18 (Table XXX), "Where does dirty water go that comes from our bathtubs, sink, and toilets?"; and Question 19, (Table XXXI) "How would you clean dirty water?"

In response to Question 17 (Table XXIX), 45 percent of the students believed that we could not run out of good clean water. A majority of children responded with either a specific misunderstanding (41%) or with "no response" (12%). These responses indicated that the students were not aware that the cleansing water cycle may not always be able to keep up with our pollution of the earth's water. Only one child of the 111 (a sixth grader) had a full understanding of this concept. His perceptive answer was "We could never run out of water, but we could run out of good clean water. We could pollute our water so bad that it could not be cleaned up or cleaned up fast enough for us to use." Some students agreed that we might run out of clean water, but could not explain why.

TABLE XXIX

RESPONSES BY PERCENTAGE TO QUESTION 17
"IS THERE SO MUCH GOOD CLEAN WATER
THAT WE COULD NEVER RUN OUT?"

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	28%	60%	1%
2	00	37	51	10
4	00	31	63	04
6	04	39	21	34
8	00	66	08	25
Average	01	45	41	12

Question 18 (Table XXX), asked students where dirty water goes. A fourth (26%) of the students had specific misunderstandings about this concept. A misunderstanding held by a large majority of the students was that after dirty water goes to the sewer, it goes to lakes, streams, rivers; or goes to the sewer and stays there. Another misunderstanding that was prevalent in the lower grades was that dirty water just "goes away." Children were unaware that water travels in a cycle. Only about half of the students could identify where dirty water goes.

TABLE XXX

RESPONSES BY PERCENTAGE TO QUESTION 18
"WHERE DOES DIRTY WATER GO THAT COMES
FROM OUR BATHTUBS, SINKS, AND
TOILETS?"

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	56%	20%	24%
2	00	82	13	06
4	00	63	31	04
6	00	56	39	00
8	00	50	25	25
Average	00	61	26	13

Question 19 (Table XXXI), asked students how to get dirty water clean. None of the students had a full understanding of how to get dirty water clean. Half of the students (50%), did not respond, apparently having no idea of how to get dirty water clean. Second graders seemed to have particular difficulty with this question, with 72 percent of the students giving no answer. Partial answers given by kindergarten, second, fourth, sixth, and eighth grade students included "pills," "sewers," "couldn't get it clean," "scoop up the mud it will stay in your hands and the clean water will fall out," "get a machine to take out all the trash," "septic tanks, put grass on bottom of lake," "dirt can't come up," "put clean water in dirty water," "wash it, take water and pour out the dirty stuff," "cure it cleaning it by rocks," "boiling the water," and "filteration plants." Only 29 percent of the students exhibited a partial understanding. The children responded with simplistic phrases to concepts they did not seem to understand.

TABLE XXXI

RESPONSES BY PERCENTAGE TO QUESTION 19
"HOW DO WE GET DIRTY WATER CLEAN?"

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	04%	60%	36%
2	00	03	24	72
4	00	40	13	45
6	00	56	08	34
8	00	75	00	25
Average	00	29	24	50

Partial understanding was had by students in regard to where dirty water goes and how we get it clean. However, 41 percent had specific misunderstandings concerning these questions. More than one-half of all students had misunderstandings, or no response concerning the concept. Table XXXII shows how students responded (percentages) on all questions involving water treatment.

TABLE XXXII

AVERAGE PERCENT FOR QUESTIONS INVOLVING WATER TREATMENT

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
All Grades	01%	45%	41%	12%

Rain

Questions 5, 7, 12, 13, and 24 dealt with the concept of rain. Of all the students, 75 percent gave responses which could be classified as partial understandings to Question 5 dealing with the concept of where rain comes from (Table XXXIII). Fourth graders had the highest percentage of partial understanding (95%). The most common answer to this question across all grade level was clouds. The majority of the students seemed to understand this concept as only 4 percent of students across grade levels did not respond. A follow-up to Question 5 (Table XXXIII), asked children to explain where rain water goes after it had fallen from the clouds. The students were unable to explain how the water got into the clouds and where the water went once it fell to the ground. Of 111 students, 75 percent exhibited a partial understanding of rainwater's pathway.

TABLE XXXIII

RESPONSES BY PERCENTAGE TO QUESTION 5
"WHERE DOES RAIN COME FROM?"

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	58%	44%	00%
2	00	95	07	00
4	00	93	04	00
6	00	78	17	04
8	00	50	25	16
Average	00	75	19	04

Question 7 (Table XXXIV), asked the children, "What makes it rain"? Overall, 54 percent of the students did not respond to this question. Kindergarten students and eighth graders had the highest number of no responses to this question. Forty-two percent of all students had some form of specific misunderstanding. Most kindergarten and second graders gave a religious answer for making it rain.

TABLE XXXIV

RESPONSES BY PERCENTAGE TO QUESTION 7
"WHAT MAKES IT RAIN?'

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	00%	08%	92%
2	00	00	38	62
4	00	10	63	27
6	00	06	73	21
8	00	08	26	66
Average	00	04	42	54

Question 12 (Table XXXV), consisted of two parts. In response to the first part, "Does it rain everytime clouds are in the sky," most children responded with no. However, follow-up questions suggested that the children had specific misunderstandings (69%) about rain and when it falls from clouds. For example, younger children often attributed the rain to deity or attributed animistic qualities to the clouds. Older children often alluded to the heaviness or density of the clouds. Also, children attributed rain to the darkness of the cloud. Their answers to Question 12 suggested they did not understand the conditions necessary to produce rain. Four graders had the highest percentage of misunderstandings with 77 percent, and eighth graders had the next highest with 69 percent.

TABLE XXXV

RESPONSES BY PERCENTAGE TO QUESTION 12
"DOES IT RAIN EVERYTIME CLOUDS ARE
IN THE SKY?"

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	28%	68%	04%
2	00	34	66	00
4	00	23	77	00
6	00	35	65	00
8	00	30	69	01
Average	00	30	69	01

The previous question (#12) asked children if "it rained everytime clouds are in the sky?" Question 12 was followed by another question to probe further their understanding, they were asked why or why not does it rain everytime clouds are in the sky? The next section will discuss the specific misunderstandings to this question. The answers the children gave were evidence that children do have alternative conceptual frameworks of where rain comes from.

Over one-half of the 25 kindergarten children gave a religious answer. Some responses were "Because Jesus wanted it to stay up in the sky, because Jesus does everything," "God doesn't want it to," "No because Jesus makes it," "God keeps it up in the sky," "Only God has the power to make it rain," "Jesus leaves it in his hands until it's time to rain," "Jesus makes it," and "No, God helps them stay up." Other responses include that "sometimes the clouds are closed and they cannot come apart," "Yes, when it's dark," and "If the moon is pointed it means there is going to be water."

Second graders also had religious theories to explain why it rains, although not as many as kindergarten students. Four of 22 second grade students had the idea that the clouds had to be dark before rain could fall. Another second grade student answered, "that the clouds had to go together and it had to thunder and lightening." Other answers included "If the sun is not shining it will not rain," "Because the clouds aren't full enough," "Because there is not enough water in the cloud to burst," or "No, because the air didn't get through to push it out." Fourth graders gave responses such as "the water is still forming" or "because the clouds aren't filled up with water yet." Answers were also given which indicated that the students thought the clouds had some control, or some decision in it raining. Such answers included "No, because it's not ready," and "No, because the clouds are holding it." One fourth grader, like some of the second graders, also thought the wind pushes the rain out of the clouds.

One sixth grader also suggested the wind pushes the rain out of the clouds, but his was a more sophisticated answer: "It rains when the weather is right, huge and super full of rain. Jet stream comes down and helps rain." Many sixth grader's answers included the idea that there was not enough rain in the cloud, that it was not full enough. Other responses to the question were "there is water up there but the clouds are just like a wall and won't let it through," and "the rain won't come down because of the thickness of the cloud." These responses suggest the students believed some type of barrier was responsible for the rain not coming down. Many students also mentioned the cloud "bursting," with the idea of a balloon being filled so full of water it would "burst." A similar response was "they are not full enough"; this answer gives the impression that the clouds somehow overflow like water in a bowl.

Four different misunderstandings were given by four eighth graders out of twelve. One student had the misunderstanding that mud made it fall; his answer was, "Yes, mud makes it fall, dust rises and evaporates and gets wet and it falls." Another eighth grader responded, "It just decides to fall." This answer indicates the student attributes human characteristics (anthrapormophism) to the rain and it can rain when the rain wants to fall. The other two answers given were, "Yes, because the clouds are not full enough" and "The clouds won't hold enough water yet so it won't fall." Both answers suggest similar understandings: that at a certain point, although the students do not know when this point is, the clouds will become full enough and rain will occur.

"What makes rain fall?" was Question 13 (Table XXXVI). Specific misunderstandings accounted for 57 percent of the responses. Second grade students had the highest percentage of misunderstanding (83%), followed by kindergarten students (68%).

TABLE XXXVI

RESPONSES BY PERCENTAGE TO QUESTION 13
"WHAT MAKES RAIN FALL?"

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	00%	68%	32%
2	00	00	83	17
4	00	20	50	38
6	00	33	30	39
8	00	09	60	31
Average	00	12	57	31

The most common misunderstanding reported by kindergarten students for why rain falls were "clouds," and "Jesus and God." Most of their answers were religious in nature. At least half of the second graders also described divine reasons, expressing beliefs as, "God ain't squished the cotton candy," "God keeps it up their till we need rain," "because God don't make it, he ain't bowling, it ain't his league day." However, half of the second graders suggested that either the darkness of the clouds, or the amount of the water in the clouds caused the rain. Examples of these are "clouds know to keep water up there," "because the clouds weren't dark yet," and "because there is not enough water in the cloud to burst."

The most frequent response offered by 4 fourth graders suggested that the clouds were too full or heavy; for example, "only so much that can be held in the cloud," "when the cloud gets filled up there is no more room," and "it gets heavy like two buckets full of water and they spill out." One fourth grader used the term evaporation in his response, but it was used incorrectly. Two fourth graders answered "moisture" is what made the rain fall. One answer was that the wind pushes the rain out of the clouds. Two answers which had not been encountered before were "Indians can make it rain," and "When a hot cloud hits a cold cloud, the cold and hot mixes together and makes water."

The majority of the answers given by sixth grade students (10 students) was "the cloud gets full of water and it falls." One student thought that the water "leaks" out of the cloud when it gets too full and then "bursts." One sixth graders' showed a slightly more sophisticated understanding of the water cycle, but still demonstrated misunderstandings. Other answers given were "the moisture in the clouds," "fog is dew which is wet and water from clouds," and "when there is more rain in the atmosphere than the clouds can handle." The primary misunderstanding held by all eighth graders was that the clouds get too full.

The last question which dealt with the concept of rain was Question 24 (Table XXXVII). This question essentially asked students to define gravity. It was expected that at least older students would understand the role gravity plays in making rain fall. However, students did not have a clear understanding of the concept of gravity. Eighty percent of the kindergarten children did not respond to the question. The older children generally exhibited a partial understanding of the concept, but none were able to relate gravity to the water cycle.

TABLE XXXVII

RESPONSE BY PERCENTAGE TO QUESTION 24
CONCEPT: GRAVITY

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
K	00%	08%	12%	80%
2	00	52	31	17
4	00	91	53	52
6	00	87	09	04
8	00	57	15	27
Average	00	59	14	28

The questions dealing with the concept of rain explored such questions as "Where does rain come from?" "What makes it rain?" "Does it rain everytime clouds are in the sky?" "What makes rain fall?" and gravity. Responses to these questions suggested that none of the students had a full understanding of the concept of rain. Table 38 shows how students responded (percentages) on all questions asking about rain. All children were aware that rain fell, and most knew it came from clouds; they, however, had no notion of causality.

TABLE XXXVIII

AVERAGE PERCENT FOR QUESTIONS INVOLVING
THE CONCEPT OF RAIN

	FULL UNDERSTANDING	PARTIAL UNDERSTANDING	SPECIFIC MISUNDERSTANDING	NO RESPONSE
All Grades	00%	38%	41%	23%

Concepts of Which Children had the Greatest/Least Understanding

The following is a list of the five questions with the highest percentage of Full Understanding and No Response by grade level. These questions represent the concepts which students knew most about (full understanding), and least about (no response) concerning the water cycle.

Kindergarten (Full Understanding). As might be expected kindergarten students did not have a full understanding of any concepts involved in the water cycle. The concept kindergarten children had the least understanding of was "Change of State." Four of the five questions having the highest percent of no responses dealt with change of state.

Kindergarten (No Response). Below are listed the questions having the highest percent of no response:

#14. "From where has the water on the outside of the jar come?" - 100% (Change of State)
#23. Concept: Condensation - 98% (Change of State)
#22. Concept: Evaporation - 92% (Change of State)
#30. Concept: Water Vapor - 92% (Change of State)
#07. What makes it rain? - 92% (Rain)

Second Grade (Full Understanding). Second grade students had a full understanding of only two questions from in the water cycle interview. Below are the concepts second graders knew most about.

#16. Is more of the earth's surface covered by land or water? - 14% (Water/Ratio)
#21. Can you drink from any well? - 10% (Groundwater)

Second Grade (No Response). Three of the questions which students knew least about dealt with change of state, one with groundwater, and one with clouds. Below are the concepts second graders knew least about:

#23. Concept: Condensation - 97% (Change of State)
#30. Concept: Water Vapor - 93% (Change of State)

9. How are clouds made? - 76% (Clouds)
#22. Concept: Evaporation - 72% (Change of State)
#28. Concept: Groundwater - 66% (Groundwater)

<u>Fourth Grade (Full Understanding).</u> Below are the four questions which fourth graders answered correctly most frequently. The percentages given indicate the frequency of correct responses. Fourth graders' highest percent of full understanding included concepts about land/water ratio, and wells.

#20. What is a well? - 44% (Groundwater)
#16. Is more of the earth's surface covered by land or water? - 41% (Land /Water Ratio)
#28. Concept: Groundwater - 14% (Groundwater)
#21. Can you drink from any well? - 6% (Groundwater)

<u>Fourth Grade (No Response).</u> However, fourth graders were not as sure as the second graders about whether or not you could drink from any well. Fourth graders did not understand concepts involved in change of state, clouds, and how to clean dirty water. Below are questions understood least by fourth graders:

#23. Concept: Condensation - 94% (Change of State)
9. How are clouds made? - 78% (Clouds)
#28. Concept: Groundwater - 59% (Groundwater)
#24. Concept: Gravity - 52% (Rain)
#19. How do we get dirty water clean? - 45% (Water Treatment)
#30. Concept: Water Vapor - 45% (Change of State)

<u>Sixth Grade (Full Understanding).</u> Unlike previous grades, a small number of sixth graders answered five questions with full understanding. However, they seemed to know more about groundwater than any other concept. Sixth graders knew most about land/water ratio and understood that we could run out of good clean water. Below are the questions which had the highest percent of full understanding:

#16. Is more of the earth's surface covered by land or water? - 70% (Land/Water Ratio)
#20. What is a well? - 35% (Groundwater)
#21. Can you drink from any well? - 2% (Groundwater)
#28. Concept: Groundwater - 4% (Groundwater)
#17. Is there so much good clean water that we could never run out? - 4% (Water Treatment)

Sixth Grade (No Response). Sixth graders knew the least about concepts dealing with clouds. Three of the five questions having no response were about the concept clouds. Concepts involved in change of state were the two other concepts sixth graders knew the least about. Condensation and water vapor were the concepts the sixth graders knew least about. Below are the five questions which had the highest percent of no response by sixth graders.

#23. Concept: Condensation - 95% (Change of State)
9. How are clouds made? - 66% (Clouds)
#11. How do clouds get into the sky? - 48% (Clouds)
#30. Concept: Water Vapor - 47% (Change of State)
8. Where do clouds come from? - 43% (Clouds)

Eighth Grade (Full Understanding). Only four responses from eighth graders indicated a full understanding of the concepts. The highest percentage of full understanding dealt with land/water ratio. The other concept fully understood by eighth grade students dealt with groundwater. Below are the four questions understood fully by eighth grade students.

#16. Is more of the earth's surface covered by land or water? - 29% (Water/Land Ratio)
#20. What is a well? - 27% (Groundwater)
#21. Can you drink from any well? - 20% (Groundwater)
#28. Concept: Groundwater - 9% (Groundwater)

Eighth Grade (No Response). The least understood concepts by eighth graders dealt with condensation. Three of the six questions having the greatest percent of no responses dealt with the concept of clouds. Change of state, groundwater, and rain were the other concepts eighth grade students did not seem to understand. Below are the questions eighth grade students knew least about.

#23. Concept: Condensation - 83% (Change of State)
7. What makes it rain? - 66% (Rain)
#11. How do clouds get into the sky? - 66% (Clouds)
#28. Concept: Groundwater - 60% (Groundwater)
6. How does water get into the clouds? - 41% (Clouds)
9. How are clouds made? - 41% (Clouds)

All Grade Levels (Full Understanding). Across all grade levels children understood most about the concept dealing with groundwater. The other two concepts students seemed to understand were water/land ratio, and whether or not we could run out of good clean water. Below are the questions all students understood the best.

#16. Is more of the earth's surface covered by land or water? - 31% (Water/Land Ratio)
#20. What is a well? - 28% (Groundwater)
#21. Can you drink from any well? - 21% (Groundwater)
#28. Concept: Groundwater - 5% (Groundwater)
#17. Is there so much good clean water that we could never run out? - 1% (Water Treatment)

All Grade Levels (No Response). The concept condensation was the least understood. It is interesting to note that the concept groundwater was most understood by all students. The responses of the question asking the children what they thought groundwater is ranked third in the no response category. "How clouds are made," "water vapor," and "What makes it rain," were also questions which students did not respond to. Below are the questions students least understood:

#23. Concept: Condensation - 93%(Change of State)
#09. How are clouds made? - 64% (Clouds)
#28. Concept: Groundwater - 60% (Groundwater)
#30. Concept: Water Vapor - 60% (Change of State)
#07. What makes it rain? - 54% (Rain)

Summary

In general, children's explanations of their concepts of the water cycle are concrete and described in physical terms. There were few indications that students had an abstract, conceptual understanding of the water cycle. Only one student exhibited a full understanding of any of the concepts discussed (water treatment). Overall, students seemed to have the least understanding of the concept dealing with change of state, specifically having to do with condensation. Fourth graders had the highest understanding of concepts dealing with the water cycle. The verbal ability of children increased with age, but general understanding of concepts did not. Many common misunderstandings apparently are derived from a child's observation of natural phenomena. These views are tenacious and can persist in the absence of informed instruction. Chief among these misunderstandings is the concept of condensation, which appears to be the weak link in the chain necessary to fully understand the water cycle.

CHAPTER V

CONCLUSIONS, RECOMMENDATIONS, IMPLICATIONS FOR FURTHER STUDY, AND SUMMARY

The primary purpose of this study was to identify, using a structured interview format, the water cycle concepts held by kindergarten, second, fourth, sixth, and eighth grade students. A secondary goal was to determine the relationships between water concept development and the following factors in the home and school environment: 1) score on the water cycle knowledge instrument, 2) cultural sources of information in the home, 3) school instructional time, 4) verbal ability, 5) child's cognitive development, and 6) gender, age, elementary achievement test scores, and parent's level of education. The following are conclusions, recommendations, implications for further study, and a summary of the descriptive data.

Research Questions: Conclusions, Recommendations, Implications for Further Study

Research Question 1

Is there a relationship between grade level and water cycle knowledge attained by the child?

Conclusions. There was a trend for mean score on the water cycle interview to increase with grade level until fourth grade. The mean scores for fourth and sixth graders were about the same. Fourth graders had a higher mean score but not significantly higher than sixth.

Recommendations. Teachers need to collaborate and inform each other as to what science concepts are being taught at each grade level. The instruction for each grade level needs to be built on what previous grades have studied.

Implications for further study. An implication that could be drawn from this "leveling off" could be accounted for by the emphasis placed on water cycle concepts in the curriculum, or by the older students studying the same concepts as fourth graders but not in more depth. It is recommended that a study be conducted to research how much instructional time is spent by teachers on selected science concepts in each grade level. How does this instructional time affect students' understanding of science concepts?

Research Question 2

What sources of information in the home relate to the child's concept of the water cycle?

Conclusions. It was concluded by the testing of the null hypothesis that home activities such as books read, programs watched, and talks with children by parents about the water cycle had little relevance to what was being taught in schools concerning the concepts of the water cycle.

Recommendations. More attention should be given to integrating the knowledge acquired in school to general knowledge, making it relevant to everyday life. Teachers could be well on their way to relevance if they used children's ideas to help teach about concepts.

Implications for further study. The implication could be made that instruction in the schools does not emphasize and connect with what children already know. It is recommended that research investigate how relevant textbooks, teaching methods, and content relate to the cultural environment of the community.

Research Questions 3

Is the amount of school instructional time spent on the study of water related to water cycle scores?

Conclusions. Fourth grade teachers spent more instructional time on the water cycle than teachers at other grade levels. Fourth grade students were generally more verbal and accurate in their responses to interview questions dealing with the water cycle. The time spent on the study of the water cycle is very limited and overall knowledge of the water cycle of students in grades K, 2, 4, 6, and 8 was not extensive. These students were "word rich" and "concept poor."

Recommendations. Teachers need to spend quality instructional time teaching water cycle concepts. Teachers need to present concepts in a more in-depth manner. Teachers need to examine children's knowledge of water cycle concepts before teaching the concepts to children. Teachers should delay teaching concepts to children until they can deal with the concepts.

Implications for further study. More instructional time is being spent by fourth graders than any other grade; however, even fourth graders' knowledge of the water cycle is low. This would imply that even though fourth graders receive more instructional time than other grade levels, this time is not significant and/or the quality of instruction is poor. Further research should be conducted to determine the amount of instructional time spent on selected science concepts and if time alone affects the misconceptions students have. Would student knowledge increase with instructional time?

Research Question 4

Is there a relationship between mean verbal ability and water cycle knowledge?

Conclusions. Although verbal ability increased with age, even younger children were more verbal when they had observed a demonstration before responding to a question. When observing a demonstration, children gave more thought to their answers even though they were not always scientifically accurate. From the answers of older students it can be concluded the older children answered from rote memory reciting definitions of words or physical concrete examples which they had seen.

Recommendations. It would be beneficial for teachers to use demonstrations, discrepant events, and experiments to promote curiosity of children and to enhance the learning of a particular science concept. If these methods were used, perhaps children's understanding and retention of water cycle concepts would increase.

Implications for further study. It could be inferred that the children interviewed were not being exposed to demonstrations, discrepant events, or experiments. A study needs to be done to determine if children's understanding of scientific concepts increase if exposed to demonstrations, discrepant events, or experiments as opposed to lecture type situations.

Research Question 5

Is there a relationship between the child's development of spatial reference frames (measure of cognitive level) and water cycle knowledge?

Conclusions. Although the correlation between a child's development of spatial reference frames and water cycle score was significant at the .05 level, the correlation coefficient was only .254. This suggests a slight relationship between the two; however, there is little predictive value in the coefficient. The relationship is not strong enough to suggest that cognitive ability leads to a better understanding of the water cycle concepts.

Recommendations. When planning instruction for children, every effort should be made to take into consideration the children's cognitive level. An understanding of the way they think and reason at different cognitive levels and an awareness of specific misunderstandings students have at particular grade levels must be considered.

Implications for further study. It can be inferred that as students progress through the grades their cognitive levels increase. Further studies are needed to determine students understanding of science lessons, and what misconceptions they have that would contribute to not understanding science lessons. Also, a study is needed of teachers to determine how much of a child's misunderstanding is because of the teachers misunderstanding of scientific concepts.

Research Question 6

Is there a relationship between the water cycle score and the age, gender, elementary achievement test scores, or parent's level of education?

Conclusions. The achievement score, as measured by the Metropolitan Achievement Test, and gender were the only two variables which were significantly related to the water cycle score. Gender accounted for a significant portion of the variance in the water cycle score. Boys scored higher than girls on the water cycle interview.

Recommendations. There is a need for teachers to become aware of the importance of the expectations we have of children and the importance of not stereotyping children according to gender. Teachers must be aware of how they interact with students and how their interaction will influence children's perception of science.

Implications for further study. Higher scores for boys could be attributed to differences in socialization of boys and girls. Boys are socialized to actively participate in their environment, while girls are socialized to remain passive observers. A study needs to conducted to determine the differences in the teaching of boys and girls in science classrooms, and whether these differences effect how a child acquires science knowledge.

The data gathered to answer Questions 7 and 8 were descriptive in nature. These data were not analyzed for statistical differences. The conclusions, recommendations, and implications for Questions 7 and 8 are combined since they are closely related. Information for Questions 7 and 8 are presented by water concept.

Research Question 7

What types of conceptual frameworks have children developed for the concepts involved in the water cycle?

Research Question 8

What proportion of the students function at each of the conceptual levels of the water cycle interview?

a. Full Understanding
b. Partial Understanding
c. Specific Misunderstanding
d. No Response

The following present conclusions, recommendations, and implications for further study.

Conclusions

Water/Land Ratio

The responses of students indicated that 31 percent had a full understanding of the concept of water/land ratio. Responses by students were not considered to be full understanding unless they could respond correctly to "How do you know more of the earth is covered by water or land?" This was the question which students understood the most. Although the concept of water/land ratio was understood by a greater percentage than all other questions it must be concluded that this question was a knowledge level question which called for a yes or no answer. The responses to water/land ratio would suggest that the children had been taught, or had inferred, the wrong information, since on chance alone, approximately 50 percent should have answered correctly.

Groundwater

Children across all grade levels knew more about groundwater than any other concept related to the water cycle. However, it must be noted that of the questions dealing with groundwater, two asked specifically about wells. The other question asked the students to define the word groundwater. It was concluded that subjects in this rural community were familiar with the term "wells," but did not understand that this water was groundwater. Not once did students associate well water with groundwater.

Change of State: Boiling

An interesting phenomenon was indicated by children's answers to questions which dealt with the concept of boiling. Children gave more complete answers and had fewer mis-understandings when they were asked to define the word boiling than when they were given a demonstration of boiling. This information supports the results of a previous study by Smith (1984) and Flegg (1981) who investigated how students' thinking might go wrong when teachers use demonstrations. Children are so busy attending to visual and auditory information supplied by the demonstration that they store terms such as condensation and evaporation in what is called "flashcard memory." These unconnected bits of information are retrievable only when the exact content is repeated. However, a conclusion of the overall data from this study suggests that science instruction for young children is most profitable when concerned with observable phenomena. Children are more likely to understand cause and effect and to be more verbal in events with which they have direct contact. With less observable events, children are likely to confuse cause and effect or consider the event as unique and without causation.

Change of State: Condensation

The concept of condensation was the least understood by students in the study. From the students' responses it can be concluded that as children get older they begin to understand that the formation of moisture is associated with the difference in temperature. Yet they were unable to explain the process of condensation. Interestingly, the answers given by eighth graders were no more accurate than those of the youngest students in the sample. Kindergarten students, with little formal exposure to the concepts of evaporation and condensation, provided answers that suggested they were attempting to think through the process of condensation. It can be concluded that concepts which are more familiar to students and more concrete like boiling or melting are easier explained by the student than more abstract concepts such as evaporation and condensation, of which observations are not as frequent. Also, children can recite a definition easier than they can explain a demonstration presented to them. It could also be inferred that students in sixth and eighth grades are puzzled by scientific concepts and are unwilling to the run the risk of speculation.

Change of State: Evaporation

The answers given to the questions which probed for an understanding of evaporation suggested that students realized that water did evaporate. However, they were unable to explain where the water went. This finding was also reported by Beveridge (1985), who also found that children's answers were situation specific. For example, the water in the pan went away (disappeared), because the water went into the pan. The water in the paper towel went into the hair dryer, or went into the towel itself.

It can be concluded that responses from the change of state questions suggest that the types of questions teachers ask are vitally important. Children can correctly answer the convergent questions posed on typical science achievement tests. All but one of the questions involving change of state were convergent. Many of the children's responses were partially correct responses of low quality. This information indicates that providing correct answers to convergent questions does not mean children understand the term or concept. The divergent questioning used in this study helped to elicit children's misunderstandings of the water cycle and showed how older children were able to camouflage their alternative frameworks by using correct terminology.

Clouds

When asked about clouds, older children were more likely to exhibit partial understanding of the concept. A finding of this study suggested that often younger children do not know the correct answer, but were less inhibited to generate answers and are more creative in their responses.

A conclusion reached by reading responses to questions about clouds indicated that children had little understanding of the water cycle as a factor in rainfall. Some phenomena about how clouds are made are difficult for young children to interpret because they do not understand the underlying related phenomena. For example, how water gets into clouds cannot be understood without knowing something about evaporation, condensation, and water vapor. It would seem from the students' responses to these questions that instruction about the more complex phenomena often leads to overgeneralized or even erroneous concepts.

Water Treatment

Many students seemed to have the understanding that the water "goes away," but they were not sure what happened to the water after it disappeared from sight. Many students could not follow the water in a complete cycle, but said the water stops in a lake, stream, or river.

These responses suggest that elementary school children do not understand that clean water is a limited resource and do not understand the relationship between the water cycle and pollution or even the processes involved in the water cycle itself. The data indicated that even if children can provide terms and definitions, they do not necessarily have an accurate understanding of the concept.

Rain

All children were aware that rain is water and most seemed to realize that rain falls from clouds. However, they had no awareness of how the rain got into the clouds. About one-half of all students realized that water could evaporate into the air, although only a few used the term evaporate. As in a previous study by Inbody (1963) nearly all younger children who did give explanations stated that Jesus or God was responsible. As would be expected from previous responses to water cycle interview questions, one-half of all students could not describe "What makes it rain?" Also, students could not explain why rain falls. Gravity was not mentioned as having an effect on rain falling. It can be concluded that children understand what rain is (physical) but did not understand how it evaporates or how rain fell from clouds.

Recommendations

Several recommendations can be drawn from the results of this study. These recommendations fall into two broad categories: teacher education and science instruction.

Recommendations for Teacher Education

1. Since this study found that children have many misconceptions concerning the water cycle it would be recommended teachers and pre-service teachers should be familiarized with specific misunderstandings they are likely to encounter among their students and methods used to displace these misconceptions.

2. Methods classes at the university level for pre- and in-service teachers must explore strategies for teaching how abstract conceptual frameworks for water cycle concepts are learned by pupils. The curriculum needs to be analyzed and evaluated to determine if the kinetic molecular theory is being taught and learned.

3. Pre- and in-service teachers need experience in diagnosing errors in student thinking and understanding methods used by students to resist accommodation.

4. Pre- and in-service education programs need to provide ways in which teachers can use demonstrations, cooperative learning activities, and simulation activities as opposed to the pure memorization of facts which are not relevant to everyday life.

5. Pre- and in-service teachers need skill in managing "hands on" experiences that can make pupils less dependable on "words" alone to understand and pass examinations.

6. In-service staff development needs to focus on determining the level of meaningful learning that students should attain.

Recommendations for Science Teaching

1. Observations made while presenting demonstrations suggested that children were not skilled at closely observing details. Children should be taught to be "trained observers," and

observe physical phenomena carefully. They also need help in interpreting their observations correctly. Process skills (observing, inferring, classifying. . .) should be emphasized over product. Process skills will enable children to be critical thinkers and thus understand concepts better.

2. Teachers should become more sensitive to their students' thinking and to the need for conceptual change. In a conceptual-change model of instruction, the teacher must realize how difficult it can be to change students' ideas. The teacher must give thoughtful consideration to how students are responding to instruction and act responsively.

3. Teachers should make use of lectures, demonstrations, problem solving, and lab experiences which can be used to create cognitive conflicts in students. A teacher might consider various types of outside activities which would create the cognitive conflict necessary to prepare for accommodation. It would be beneficial to have discrepant event activities included in the lesson to create cognitive dissonance and stimulate children's accommodation of more scientifically correct concepts involving the water cycle.

4. Teachers should help students make sense of science content by presenting content in a variety of modalities (learning styles) such as written, physical, oral, concrete, and pictorial.

5. Teachers can select textbooks more carefully, taking more time to examine the full range of texts available and then choosing one that presents concepts clearly, interestingly, and comprehensively. Textbook reviews should identify material which may contribute to children's "alternative frameworks." Teachers' textbook guides need to include ideas for sequential concrete experiences for teaching concepts such as evaporation, condensation, groundwater, clouds, rain, and water treatment.

6. Teachers must present the entire water cycle as a set of interrelated concepts. Some phenomena are difficult for young children to interpret because of a misunderstanding of the related underlying principles. For example, many phenomena concerning the water cycle cannot be explained without understanding the concepts involved in the whole water cycle.

Teaching of definitions does not contribute to a understanding of interelatedness of water cycle concepts.

7. Teachers should keep track of the science misconceptions they encounter so they may correct them when planning and carrying out instruction. Teachers cannot assume that concepts taught in previous years have been fully understood by the students. Nor can they assume that all naive concepts or misconceptions have been correctly altered by the student.

8. When teaching, the conceptual frameworks of the student should be used first. If the students' frameworks are used (and modified, if need be), teaching can be made relevant.

9. It is recommended that teachers find out what students really know. A good way to do this would be to put them where they must overtly construct or perform an act that creates a product that can be evaluated—not a word.

10. Teachers should collaborate to find effective strategies for identifying students' misunderstandings. A teacher can use a fellow observer (another teacher) to watch students closely and determine what their misunderstandings are. On the basis of observations by the fellow observer, the teacher can then try teaching differently.

11. Another way teachers can identify student misunderstandings is through their writing. Asking students to write about what they have learned forces them to first think about the information and then give an explanation of what they understand.

12. Teachers, like all adults, may have the same misunderstandings that their students do. It is recommended that science curriculum materials be well-written. This would be one way in which teachers may be able to correct their own misunderstandings as they use the materials.

13. More attention should to be given to interrelating the knowledge acquired in school with knowledge the student has acquired from life experiences.

14. Teachers should use appropriate questions to stimulate higher level thinking skills.

15. It appears that demonstrations can help children understand, but not all demonstrations can be applied to real world situations. It would be recommended that teachers

be careful of the demonstrations they use so as not to cause further misconceptions to be developed by the student.

16. Teachers need more content courses or workshops so they may find out what misconceptions they possess and displace these misconceptions with scientifically acceptable ones. Also, the use of in-service of workshops which are very narrow in their focus, i.e., the water cycle, would seem appropriate.

17. It is recommended that concepts of the water cycle be studied together so as to understand how one concept is related to others. Tests should be developed that measure students' understanding of the interrelatedness of water cycle concepts.

18. It is recommended that teachers understand how a child might think about an abstract concept, and how this might differ from the way an adult would think of the same concept.

19. A recommendation from this study would be for teachers to study demonstrations they might use in the classroom, and see how children might be confused by, or misinterpret these demonstrations.

20. It is recommended that teachers be familiar with a variety of questioning techniques that elicit more than knowledge-level answers.

21. In general the findings imply that teachers need to redesign their instruction to identify and accommodate children's "alternative frameworks."

Implications for Further Study

1. It can be implied from this and other research that in trying to understand concepts they encounter in school and out, children incorporate faulty ideas into their own alternative framework. They end up with a myriad of explanations, none of which fits to form a scientifically correct concept. Research needs to be undertaken to learn more about misconceptions children have regarding other science concepts.

2. It could be implied the reason for older students not being as creative or verbal in their responses is that these students knew what answers were incorrect, but did not know the scientifically correct answer so they would not answer the question. When they did respond their answers included words which sounded better but were not more correct than those given by younger counterparts. A study should be undertaken to examine how older students' answers differ from younger students.

3. Pupils do not understand the concepts involved in the water cycle. Teachers were spending time on the water cycle yet knowledge was not there. It can be implied that teaching is not happening, or is not effective. Part of the problem could be textbooks or curriculum. A study needs to be conducted to examine science textbooks and curricula in order to evaluate how they might contribute to childrens' "alternative frameworks."

4. Although students may do well on achievement tests, it can be implied that current testing and evaluation is not measuring understanding. Research needs to be conducted to design tests that measure understanding, not merely remembering words.

5. During the interviews, children were intrigued by the demonstrations and actively searched for explanations although they were unscientific. Many teachable moments were created. It can be implied that instruction which focuses on the creative thinking of children when motivated by visual, concrete experiences is valued in classrooms. Research needs to be conducted in order to compare classrooms which value creative thinking and those which do not.

6. Another implication from this study suggests that the type of questions asked by teachers is vitally important. Children can correctly answer the convergent questions posed on the typical science achievement test, but as these data clearly indicated, providing correct answers to convergent questions does not mean children understand the term or the concept. The divergent questioning used in this study helped to elicit children's misunderstanding of the water cycle. It also revealed how older children were able to camouflage their "alternative frameworks" by using the correct terminology. It can be implied that low level questions, although answered correctly, fail to measure a student's understanding of a concept. Research needs to

be undertaken to examine the questioning techniques of teachers and how these might influence a child's learning or the misconceptions he/she many develop.

7. A concomitant implication can be leveled directly at science education. What does it matter if a child has a misconception? The most important thing to learn and, therefore, test, is the correct definition of scientific terms. If the concern is only for achievement test scores, then there is no reason for teachers to change science instruction. A study is needed to determine how much science curriculum is tailored to meet requirements of science achievement tests and to examine achievement tests to determine if they foster any misconceptions for the student.

8. The concept "boiling" was better understood by students who were asked to define boiling before rather than after seeing the demonstration. It can be implied that with so many facts to attend to, students become confused. Research should be undertaken to determine how classical science demonstrations and experiments can go wrong and cause misconceptions among elementary students.

9. It could be implied from the study that the interdisciplinary approach to teaching is not used. Research should be directed in trying to find out where faulty ideas that children hold originate. It is proposed that a study be undertaken to examine the understanding of water concepts of elementary and pre-service teachers.

10. Demonstrations or questions asked students involving the concepts of boiling, melting, and freezing seemed to be better understood than the concepts of condensation and evaporation. It could be implied that a child understands a concept better if he/she is familiar with the physical phenomenon for which it is the label. A study should be launched to determine how a child's concept development differs between an abstract concept and an abstract concrete concept. Does this development have any bearing on how the child learns the concepts and on the misconceptions he may develop?

Summary

As expected, kindergarten students had no full understanding of the concepts making up the water cycle. The concepts making up change of state had the highest percentage of no responses. Perhaps kindergarten children knew less about these terms because they had not been exposed to this terminology. The terms dealing with change of state, condensation, evaporation, and water vapor represent abstract ideas far above the development of kindergarten students. Children did know more about change of state terms such as boiling, melting, and freezing. Perhaps personal experience with these concepts helped the kindergarten children to understand them better. Also, concepts involving clouds and rain elicited much greater response.

Younger elementary students gave responses based on common sense and had not yet been encumbered with scientific terminology. Many of the older students seemed to be so concerned with trying to fit the correct scientific terms into their explanations that they lost sight of the phenomena at hand. This may indicate that teachers emphasize terminology so much that students lose sight of the meanings behind the vocabulary.

One of the major impressions was that children can associate a technical term, sometimes the appropriate technical term, with an event. The students knew what term to respond with when asked about a demonstration. However, further questioning of children of all ages about what they actually meant left this author with a strong impression that even the older children had no sound scientific understanding of these terms. Also, children sometimes used scientific knowledge to support their nonscientific ideas. For example, a sixth grade student stated that the water comes through the glass by evaporation. The students were familiar with the terminology, but were confused on how it fit together to form a complete picture of the water cycle.

In conclusion, this study confirms other studies in the area of children's alternative frameworks about the water cycle. Children can bring to science lessons strongly held views about how and why everyday things behave as they do. In relation to their experiences, these views appear, to them, to be logical and sensible. Moreover, the views can remain uninfluenced or can be influenced in unanticipated ways by science teaching.

Older students held similar views to younger children despite the fact that the older students had considerably more exposure to science instruction. Findings from this study indicated that although students can often associate the appropriate technical terms with a concept such as evaporation, condensation, or change of state, many students have no scientific conceptual model to explain these terms.

The research reported supports previous investigations of (Cosgrove & Osborne, 1981) water cycle concepts, showing the prevalence of alternative frameworks in children even after receiving formal instruction. The design of science curriculum and instruction is likely to improve only if students' prior knowledge of natural phenomena is considered.

A number of independent variables were found to be significantly related to the variance in Water Cycle Assessment Scores held by children. Some of the independent variables studied were gender, grade, parent's years of education, elementary achievement scores, verbal ability, and spatial ability. Verbal ability, spatial ability, elementary achievement scores, and gender were determined to be the more reliable predictors of water cycle assessment scores. The teacher surveys were successful in identifying instructional time spent on water cycle concepts.

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APPENDIXES

APPENDIX A

ANSWERS TO INTERVIEW QUESTIONS

(VALIDATED ANSWERS)

SOUND UNDERSTANDING

These sound understandings correspond to interview questions asked the kindergarten, second, fourth, sixth, and eighth grade students.

Question 1. I am going to light this candle under this pan which has water in it. Will anything happen to the water?

Liquid water changes to gas when heat energy is added. Heat energy becomes molecular kinetic energy within the body. As a body gains heat, its molecules vibrate faster and faster. The molecules move farther away from each other which lessens their attraction for one another. Some of these molecules which are close to the surface escape from the surface of the liquid and become water vapor. This process of escaping molecules is called evaporation.

Heat energy is added

Heat energy becomes molecular kinetic energy

Molecules move faster

Molecular attraction is lessened

Fast moving molecules on the surface escape

Question 2. I am going to put a wet spot on this paper towel and turn this hair dryer on the wet spot. What will happen to the wet spot?

The heat from the hair dryer becomes molecular kinetic energy. The molecules in the liquid spot vibrate faster and faster. The molecules move farther and farther apart which lessens the attraction between the molecules. The molecules escape into the air as water vapor. The hair dryer blows this water vapor away replacing it with air that has less moisture so that more molecules can escape in the air.

Heat energy is added

Heat energy is changed to molecular kinetic energy

Molecules move faster

Molecules are farther apart

Molecular attraction is lessened

Fast moving surface molecules escape

Fan blows the water vapor away allowing more molecules to escape

Questions 3 and 4. What causes the clothes to dry? (The child will be shown a picture of clothes drying on a clothes line.)

The heat from the sun becomes molecular kinetic energy. The water molecules in the clothes vibrate faster and faster. The molecules move farther and farther apart which lessens the attraction between the molecules. Molecules begin to escape into the air as a gas called water vapor. This process is called evaporation. The air can only hold so much water vapor. If the wind blows, it can carry the water vapor away. This will make it possible for more water molecules to escape from the clothes. The clothes will dry faster.

Sun provides source of radiant energy

Radiant energy changed to molecular kinetic energy

Increase of kinetic energy means molecules are moving faster, moving farther apart, and losing attraction to one another

Surface molecules escape

Water has a new state: gas (water vapor)

Wind carries water vapor away making surrounding air less saturated with water vapor therefore allowing more surface molecules to escape

Questions 3 and 4. Can we see the water after it leaves the clothes?

No

Questions 3 and 4. Can we still call it water?

Yes, but it is in a gaseous form

Questions 6, 8, 9, 10 and 11. How do clouds get in the sky?

Air near the surface of the earth is heated and cooled unequally. The radiant energy from the sun heats up the land faster than the water. This occurs for two reasons. First, the sunlight penetrates only a short distance below the top of the soil but more deeply into water. Second, water has a higher heat capacity than land. During the day, the air above the land is heated by the ground and begins to expand. The cooler, heavier air over the water rushes in and pushes the expanded, lighter air upward. During the night, the water is warmer than the land so the warm air above the water is pushed upward by the cooler air from the land.

Air near surface heated and cooled unequally

Air above land warmer than air above water in the daytime

Warm air expands and becomes lighter

Cool air pushes warm air upward

Question 8. How are clouds formed?

Water molecules escape from liquid on the earth through the process of evaporation and become water vapor. This warm gas expands making it lighter than cooler air which causes the warm air to rise. As the gas rises, it expands more because the pressure is decreased. The molecules do not collide as often. Heat is taken from the water vapor. Removal of heat energy slows down the movement of the water molecules. As the molecular motion slows down, the molecular attraction becomes stronger. Water molecules become closer and closer to each other until liquid is formed. The attachment occurs more readily if condensation nuclei (dust, smoke particles, etc.) are present for those molecules to attach to. The process of condensation has occurred. These clusters of water molecules or particles can be seen as clouds.

Radiant energy turns to molecular kinetic energy

Increased molecular kinetic energy increases the possibility of water evaporation

Warm air expands and rises

Air pressure decreases as the water vapor rises causing the water vapor to expand

Molecules do not collide as often

Heat is removed

Molecular motion slows down

Molecular attraction increases

Molecules become closer and closer

Presence of condensation nuclei

Condensation occurs

Questions 5, 12, and 13. What makes it rain? (Does it rain everytime clouds are in the sky?)

Precipitation depends on several factors. The air must be saturated with water vapor. In order for that water vapor to condense, the temperature of the air must fall below the dew point. The presence of particles in the air may quicken condensation. When the water molecules that have attached to the particles become sufficiently heavy to overcome the updraft of air, these clusters will be pulled toward the earth.

Air contains all the water vapor it can hold (saturated)

Temperature of air falls below dew point

Particles present in the air

Water molecules attach to the particles

The cluster of molecules large enough to overcome updraft of air

Gravity will pull clusters to the earth

Question 14. From where has the water on the outside of the jar come? (A dry jar had been filled with water and ice.)

The water molecules in the air, water vapor, collide with the cold jar sides which removes heat from the molecules causing the gas to become liquid.

Water vapor in the air

Molecules collide with sides of the jar

Sides of jar are below dew point

Heat is removed from air next to jar

Molecules slow down and are more attracted to one another

Condensation occurs on the sides of the jar

Question 15. What is the difference about water forming on the outside of a cold glass jar, and water disappearing from a puddle into the air on a sunny day?

One is evaporation, and one is condensation

Question 16. Is more of the earth's surface covered by water or land?

Water (over 70%, less than 75%) 71 percent

Question 17. Will we ever run out of good clean water? Why or why not?

The amount of water basically remains constant on the earth. If man pollutes this supply, we could run out of good clean water. Right now less than 10 percent of the world's population has access to drinkable water. Appropriate purification of water takes time whether it's done naturally or through treatment. With the increase of population in the world, the demand for usable water becomes greater. Water conservation must be practiced if we are to meet the demands.

Amount of water remains constant

Pollution

Purification of water

Water conservation

Question 18. Where does the bathroom, sink, and toilet water go?

To septic tank

Sedimentation

Filtered through rocks and soil

Or to a water purification plant

Or released unclean into lakes or rivers

Question 19. How would you get it clean?

Evaporation purifies unclean water. As water flows through the rocks and soil, this helps purify the water. Boiling purifies water. Sewage and industrial wastewater must undergo treatment. Filters and sedimentation help remove suspended solids and reduce the oxygen demand. Certain bacteria are used to decompose the waste. Finally, chemicals are used to remove specific pollutants.

Evaporation

Boiling

Distillation

Flowing through soil and rocks

Water purification plant

Filters and sedimentation

Bacteria which eats waste

Chemicals

Question 20. What is a well?

Rainwater absorbs into the soil and porous rock. This water continues to sink down into the earth until it reaches a layer of solid, nonporous rock which holds the ground water. As more rainwater soaks into the ground, more of the ground becomes saturated with water. The top of this saturated ground is called the water table. A hole is dug to some depth below the water table. The part of the hole that is below the water table will fill with water.

Ground water

Layer of solid, nonporous rock

Water table

Hole deeper than the water table

Question 21. Can you drink from any well?

No

Question 21. Why or why not?

Not if pollutants are present. Pollutants may include

Heavy metals: mercury, lead, cadmium, etc.

Pesticides and herbicides

Oil

Synthetic detergents (phosphates)

Bacteria or virus (feces and urine of humans or animals)

Acid rain

Question 21. Can you drink from any pond, lake, stream, or river? Why not?

No, not if pollutants are present. Pollutants may include

Heavy metals

Pesticides and herbicides

Oil

Synthetic detergents

Bacteria or virus

Acid rain

Question 22. Define evaporation.

Liquid changes into a vapor. The particles at the surface of the liquid with the highest kinetic energies (meaning they are moving the fastest and therefore their attraction to other molecules is the least) are able to break out of the liquid thus changing from liquid to vapor. When the air above the liquid water is completely saturated with water, then the water will not evaporate.

Heat increases kinetic molecular energy

Molecules moving fast

Molecules move farther apart, lessening molecular attraction

Surface molecules can escape from liquid if air above the liquid is not saturated.

Question 23. Define condensation.

Vapor changes into liquid. When heat energy is taken away, particles lose energy, move slower, and become closer together. As the particles are attracted to one another, liquid is formed.

Changing from the gas form to the liquid form of water

Heat is taken away

Molecules slow down and become more attracted to one another

Question 24. Define gravity.

A force that tends to pull every particle of matter toward every other particle. Those particles are pulled toward the center of the earth.

Force

Pulls particles of matter toward each other

Pulls matter toward the center of the earth

Question 25. Define melting.

Enough heat energy has been added to allow the particles to move so fast that the particles can no longer hold their orderly arrangement.

Kinetic molecular energy has been increased by adding a heat source

Molecules move faster and farther apart

Molecules no longer hold their orderly arrangement

Solid looses its shape

Question 26. Define boiling.

As water is heated, its temperature rises which means the movement of the molecules increases. Secondly, the vapor pressure increases. The vapor pressure becomes equal to the pressure of the atmosphere at 100 degrees Celsius. Boiling, which is the formation of vapor bubbles throughout the liquid, takes place at this temperature.

Heat added

Movement of molecules increases

Temperature is 100 degrees Celsius

Vapor bubbles form

Pressure

Question 27. Define freezing.

Heat is removed which means the molecules slow down. When the molecules slow down the temperature lowers. When the temperature is 0 degrees Celsius, water becomes ice. (Pressure the same.)

Heat removed

Molecules slow down

Temperature at 0 degrees Celsius

Liquid becomes a solid

Pressure

Question 28. Define groundwater.

Water penetrates the earth's crust and is trapped in the soil and rock spaces. This is found in the zone of saturation.

Water beneath the earth's surface

Held in the soil and rock spaces

Question 29. Define steam.

When water boils, some of the molecules escape into the air becoming water vapor. If the water vapor is cooled enough by the surrounding air, it condenses into tiny droplets of liquid water. The presence of these droplets makes the water visible. This is steam.

Evaporation

Water vapor cooled by surrounding air

Condenses

Becomes visible droplets

Question 30. Define water vapor.

Water vapor is water in a gaseous state which is invisible to the eye.

Different form of water

Gas

Invisible

APPENDIX B

SOURCES OF INFORMATION IN THE HOME

Olive Public Schools

"Home of The Wildcats"

Route 1, Box 337 • Drumright, Oklahoma 74030
Telephone 918-352-9568

Dear Parents,

Recently your child participated in a project aimed at identifying his/her notions of the water cycle. Some of the water cycle notions that were investigated were: evaporation, condensation, boiling, water vapor, gravity, groundwater, melting, and steam. Children's notions of the water cycle develop as a result of both maturation and home experiences. The home as well as the school offer such experiences. The following questions are designed to identify sources of information in the home that have contributed to your child's understanding of the concepts involved in understanding of the water cycle. Your participation will be very helpful in improving teaching strategies and curriculum development.

Please respond to the following questions indicating the amount of time in each experience on a scale of 1-5 (where 1 is little or no time spent and 5 is a great deal of time). All responses will be kept completely confidential.

After completing the questionnaire, please have your child return it to his/her teacher. Thank-you for your time and cooperation.

Sincerely,

Mark McJunkin

Beth Crabtree

WE STRIVE FOR ACADEMIC EXCELLENCE

***********Dear Parents,some questions may seem out of place or*************
***********unusual but are important to the study.***************************
(No Name Needed)

BACKGROUND INFORMATION

Father's occupation________________________________

Mother's occupation________________________________

Highest educational level completed:

1. Mother________________

2. Father________________

What degree if any of Indian blood is your child______________

Approximate yearly income (OPTIONAL)____________________________

Sources of Information in the Home

		TIME SPENT				
		Little			Much	
1.	How much time has your child spent on lakes and rivers in the state of Oklahoma?	1	2	3	4	5
2.	How much time has your child spent at science and space museums such as the Omniplex?	1	2	3	4	5
3.	How frequently does your child watch the following television programs:					
	a. Nova	1	2	3	4	5
	b. NASA programs	1	2	3	4	5
	c. Karl Sagan programs	1	2	3	4	5
	d. 321 Contact	1	2	3	4	5
	e. National Geographic specials	1	2	3	4	5
	f. Educational programs in general	1	2	3	4	5
4.	How frequently do you discuss these programs with your child?	1	2	3	4	5
5.	During a week how often does your child spend watching the television weather report?	1	2	3	4	5
6.	How often does your child have the responsibility of feeding animals.	1	2	3	4	5
7.	How often does your child use a hair dryer?	1	2	3	4	5

	TIME SPENT				
	Little			Much	
8. How often do you talk with your child about condensation and evaporation?	1	2	3	4	5
9. How often have you talked with your child about drought and its effect on the land and people?	1	2	3	4	5
10. How much time is spent by your child in maintaining a garden, doing the watering etc....?	1	2	3	4	5
11. How much time do you spend discussing the effects of floods on the land?	1	2	3	4	5
12. How much time is spent by your child reading and looking at science related books or magizines which may discuss water related topics?	1	2	3	4	5
13. How much time is spent by your child in organizations such as Boy Scouts, Girl Scouts, Blue Birds, etc.......?	1	2	3	4	5
14. How much time does your child spend looking at globes or maps in your home?	1	2	3	4	5
15. How much time do you spend talking about the ponds and creeks on your property?	1	2	3	4	5
16. If you receive your water from a well how much time do you spend talking to your child about how the well works and where the water comes from.	1	2	3	4	5

Please list any other experiences your child has had that might contribute to his/her understanding of water cycle concepts which deal with melting, condensation, gravity, evaporation, gravity, evaporation, boiling, water vapor, ground water and steam.

Parent Survey: Tallies by Grade and Total

Sources of Information in the Home

1. How much time has your child spent on lakes and rivers in the state of Oklahoma?

	Time Spent: Little 1	2	3	4	Much 5	mean
K	3	-	1	1	2	2.85
2	1	2	3	4	2	3.36
4	4	3	2	5	2	2.87
6	4	2	5	3	-	2.50
total	12	7	10	13	6	2.87

2. How much time has your child spent at science ans space museums such as the Omniplex?

	Little 1	2	3	Much 4	5	mean
K	5	2	-	-	-	1.28
2	5	5	1	-	-	1.63
4	9	4	1	2	-	1.75
6	11	3	1	-	-	1.33
total	30	14	3	2	-	1.53

3. How frequently does your child watch the following television programs:

a. Nova

	Little 1	2	3	Much 4	5	mean
K	4	2	-	1	-	1.71
2	6	2	1	2	-	1.90
4	6	1	5	2	2	2.56
6	5	4	5	-	2	2.37
total	21	9	11	5	4	2.24

b. Nasa programs

	Little 1	2	3	Much 4	5	mean
K	6	1	-	-	-	1.14
2	7	1	2	1	-	1.72
4	3	5	4	2	1	2.53
6	9	3	3	-	-	1.60
total	25	10	9	3	1	1.85

c. Karl Sagan programs

	Little 1	2	3	Much 4	5	mean
K	4	1	-	-	-	1.20
2	9	1	2	-	-	1.41
4	13	1	2	-	-	1.31
6	13	-	1	1	-	1.33
total	39	3	5	1	-	1.33

d. 321 Contact

	Little 1	2	3	Much 4	5	mean
K	3	-	2	-	-	1.80
2	7	2	1	-	-	1.40
4	9	1	5	2	-	2.00
6	11	-	2	1	1	1.73
TOTAL	30	3	10	3	1	1.76

e. National Geographic specials

	Little 1	2	3	Much 4	5	mean
K	–	1	4	–	2	3.42
2	5	–	2	3	1	2.54
4	1	2	2	4	6	3.80
6	4	3	4	–	4	2.80
total	10	6	12	7	13	3.14

f. Educational programs in general

	Little 1	2	3	Much 4	5	mean
K	–	1	3	1	2	3.57
2	2	2	4	1	2	2.90
4	2	2	4	5	4	3.41
6	3	3	6	–	3	2.80
total	7	8	17	7	11	3.14

4. How frequently do you discuss these programs with your child?

	Little 1	2	3	Much 4	5	mean
K	–	2	2	2	1	3.28
2	2	4	2	3	–	2.54
4	2	4	4	4	1	2.86
6	5	3	5	2	–	2.26
total	9	13	13	11	2	2.66

5. During a week how often does your child spend watching the television weather report?

	Little 1	2	3	Much 4	5	mean
K	1	1	1	2	2	3.42
2	–	2	6	1	2	3.27
4	4	3	3	4	2	2.81
6	5	5	3	1	1	2.20
total	10	11	13	8	7	2.81

6. How often does your child have the responsibility of feeding animals.

	Little 1	2	3	Much 4	5	mean
K	–	–	1	2	3	4.33
2	–	–	1	4	6	4.45
4	4	2	5	–	5	3.00
6	2	1	4	3	5	3.53
total	6	3	11	9	19	3.66

7. How often does your child use a hair dryer?

	Little 1	2	3	Much 4	5	mean
K	2	1	3	–	–	2.57
2	3	3	3	1	1	2.45
4	8	1	5	1	1	2.12
6	8	1	2	1	3	2.33
total	21	6	13	3	6	2.32

8. How often do you talk with your child about condensation and evaporation?

	Little 1	2	3	Much 4	5	mean
K	2	4	–	–	–	1.66
2	4	6	–	1	–	1.81
4	9	4	2	1	–	1.68
6	13	2	–	–	–	1.13
TOTAL	28	16	2	2	–	1.54

9. How often have you talked with your child about drought and its effects on the land and people?

	Little 1	2	3	Much 4	5	mean
K	1	3	1	2	-	2.57
2	3	6	-	2	-	2.09
4	7	2	4	3	-	2.18
6	5	2	4	4	-	2.46
total	16	13	9	12	-	2.34

10. How much time is spent by your child in maintaining a garden, doing the watering etc....

	Little 1	2	3	Much 4	5	mean
K	-	-	1	2	4	4.42
2	3	2	3	1	2	2.54
4	5	3	3	2	3	2.68
6	2	5	1	6	1	2.93
total	10	10	8	11	10	3.02

11. How much time do you spend discussing the effects of floods on the land?

	Little 1	2	3	Much 4	5	mean
K	-	2	4	1	-	2.85
2	4	3	3	1	-	2.09
4	5	6	3	2	-	2.12
6	3	3	5	3	1	2.73
total	12	14	16	7	1	2.42

12. How much time is spent by your child reading and looking at science related books or magizines which may discuss water related topics?

	Little 1	2	3	Much 4	5	mean
K	1	3	2	1	-	2.42
2	4	4	2	1	-	2.00
4	2	2	9	1	-	2.81
6	9	4	1	1	-	1.60
total	16	13	14	6	-	2.20

13. How much time is spent by your child in organizations such as Boy Scouts, Girl Scouts, Blue Birds, etc...

	Little 1	2	3	Much 4	5	mean
K	3	2	1	-	-	1.66
2	6	2	1	-	2	2.09
4	8	2	2	3	1	2.18
6	10	-	-	3	2	2.13
total	27	6	4	6	5	2.08

14. How much time does your child spend looking at globes or maps in your home?

	LIttle 1	2	3	Much 4	5	mean
K	-	1	4	1	1	3.28
2	5	3	3	-	-	1.81
4	4	3	6	3	-	2.50
6	6	4	4	1	-	2.00
total	15	11	17	5	1	1.95

15. How much time do you spend talking about the ponds and creeks on your property?

	Little 1	2	3	Much 4	5	mean
K	-	-	3	3	-	3.50
2	2	3	4	1	1	2.63
4	2	-	8	4	2	3.25
6	5	2	3	2	3	2.73
total	9	5	18	10	6	2.97

16. If you receive your water from a well, how much time do you spend talking to your child about how the well works and where the water comes from.

	Little 1	2	3	Much 4	5	mean
K	1	2	3	-	-	2.33
2	3	5	1	2	-	2.18
4	5	5	4	2	-	2.18
6	5	7	2	1	-	1.93
total	14	19	10	5	-	2.12

APPENDIX C

PARENTAL PERMISSION FORM

Olive Public Schools

"Home of The Wildcats"

Route 1, Box 337 • Drumright, Oklahoma 74030
Telephone 918-352-9568

April 1, 1987

Dear Parents:

As part of our continuing effort to improve our Elementary Science curriculum, we are supporting a study into children's concepts in earth science. To do this we are requesting of all participating parents to permit the use of anonymous student scores on the achievement test. It is not necessary to know what student has what score, only that groups of scores be compared.

We would appreciate your cooperation in signing this letter and returning it to school by Friday, April 3, 1987.

Sincerely,

Mark McJunkin

Beth Crabtree
Principal

____
Parent's signature

I give my child permission to be in the study and his/her scores to be used anonymously.

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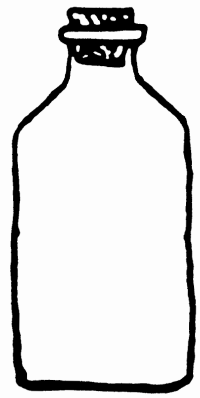
APPENDIX D

WATER LEVEL TASK



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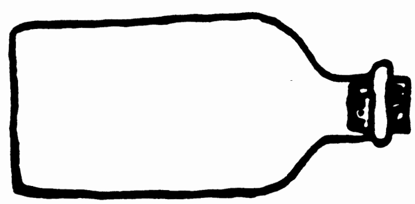

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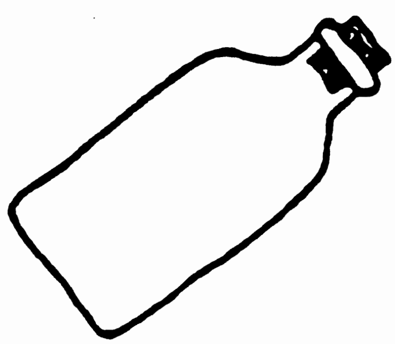

APPENDIX E

INSTRUCTIONAL TIME SPENT ON WATER CYCLE CONCEPTS BY TEACHERS

Instuctional Time Spent on Water
Concepts Survey
(Teacher Survey)

1. What grade do you teach?______

2. How many years have you taught at this grade level?______

3. How much time was spent in your classroom this year on water cycle concepts?

   (a.) 20 minutes (b.) 60 minutes (c.) 90 minutes (d.) More than 90 minutes

APPENDIX F

VERBAL OPPOSITES WORD LIST

Verbal Opposites

1.	boy	25.	asleep	49.	dangerous	73.	create
2.	front	26.	come	50.	victory	74.	passive
3.	up	27.	add	51.	begin	75.	autocracy
4.	brother	28.	laugh	52.	deep	76.	reject
5.	wet	29.	daughter	53.		77.	loiter
6.	dirty	30.	strong	54.	lengthen	78.	ignorant
7.	young	31.	narrow	55.	costly	79.	diminish
8.	hot	32.	false	56.	succeed	80.	gradual
9.	dead	33.	love	57.	imprisoned	81.	abstract
10.	crooked	34.	remember	58.	entrance	82.	expand
11.	carly	35.	pretty	59.	falsehood	83.	discord
12.	sour	36.	stale	60.	lend	84.	epilogue
13.	shut	37.	blond	1.	timid	85.	superflous
14.	empty	38.	absent	62.	profit	86.	naive
15.	noisy	39.	same	63.	former	87.	anabolism
16.	tight	40.	raw	64.	vertical	88.	cause
17.	lost	41.	cruel	65.	maximum	89.	intermitte
18.	north	42.	after	66.	complex	90.	synthesis
19.	sick	43.	sharp	67.	bless	92.	clergy
20.	off	44.	evening	68.	unite	93.	diurnal
21.	black	45.	friend	69.	convex	94.	magnify
22.	heavy	46.	multiply	70.	asset	95.	corpulent
23.	near	47.	wild	71.	inferior	96.	ecstasy
24.	smooth	48.	puddle	72.	optomistic		

APPENDIX G

WATER CYCLE INTERVIEW

1. I am going to light this candle under this pan which has water in it, will anything happen to the water?

2. I am going to put a wet spot on this paper towel, and turn this hair dryer on the wet spot, what will happen to the wet spot?

3. (Picture of clothes hanging on a line)
What causes the clothes to dry? explain

4. Where do you think the water goes?
Can we see the water after it leaves the clothes?
Can we still call it water? Is it the same water? The difference?

5. Where does rain come from?(follow up)

6. How does water get in the cloud?

7. What makes it rain?

8. Where do clouds come from?

9. How are they made?

10. What do you think clouds are made of?

11. How do they get up in the sky?

12. Does it rain everytime clouds are in the sky?
    a. Is their water up there?
    b. If so why doesnt it fall down?

13. What makes rain fall?

14. From where has the water on the outside of the jar come?

15. What is the difference about water forming on the outside of a cold glass jar, and water disapearing from a puddle into the air on a sunny day?

16. Is more of the earths surface covered by water or land?why?

17. Is there so much good clean water that we could never run out?

18. Where does dirty water go that comes from our bathtubs, sinks, and toilets?

19. How would you get this water clean?

20. What is a well?Where does the water come from?Drink from any well?why or why not?

21 Can you drink from any well? why or why not?

22 evaporation

23. condensation

24. gravity

25. melting

26. boiling

27. freezing

28. ground water

29. steam

30. water vapor

2

VITA

Mark Andrew McJunkin

Candidate for the Degree of

Doctor of Education

Thesis: ELEMENTARY CHILDREN'S CONCEPTS OF THE WATER CYCLE

Major Field: Curriculum and Instruction

Biographical:

Personal Data: Born in Tahlequah, Oklahoma, May 14, 1956, the son of Virgil and Gertrude McJunkin.

Education: Graduated from Tahlequah High School, Tahlequah, Oklahoma in May, 1974; received the Bachelor of Science degree in Elementary Education from Northeastern Oklahoma State University in May, 1978; received Master of Science degree at Northeastern Oklahoma State University in July, 1981; completed requirements for the Doctor of Education degree at Oklahoma State University in May, 1991.

Professional Experience: Fifth and sixth grade teacher, Tahlequah, Oklahoma, August, 1978, to May, 1986; Graduate Assistant, Department of Curriculum and Instruction, Oklahoma State University, August, 1986, to May, 1988; Assistant Professor, Department of Elementary Education, Arkansas State University, August, 1989, to present.