# PRESERVICE ELEMENTARY SCHOOL TEACHERS' 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 requirements for
the Degree of
DOCTOR OF EDUCATION
May, 1992

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## ACKNOWLEDGMENTS

I wish to express sincere appreciation to my adviser, Dr. Ted Mills. I am grateful for his guidance and enthusiastic support for this research topic. His knowledge regarding and devotion to the environment are exemplary. I have learned a great deal thru this dissertation process and research and the information is valuable in my present responsibilities in teacher education. I want to express appreciation to the other members of my committee, Dr. Gerald Bass, Dr. Russ Dobson, Dr. Vernon Troxel, and Dr. David Yellin for their encouragement and suggestions. My thanks also go to Iris McPherson for her help with the computer analysis of the research data and to Chris Moseley for her help with collecting data from the Oklahoma State University students.

I would also like to thank and acknowledge my parents, Charles and Susie Van Thiel, for their support and encouragement through the years. They have always highly valued education and have helped me internalize a desire for high standards in my life.

A special thanks is due my friend and mentor, Dr. Ida Adolphson who has provided constant support, help, and moral encouragement throughout these years.

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# CHAPTER I

# INTRODUCTION

A recent concern of science education is that all citizens in our democracy acquire scientific literacy (Linn, 1987) so that individuals may make appropriate decisions in our technological society. One of the characteristics that Oickle (1972) uses to define a scientifically literate person is that an individual "should acquire knowledge which can be used to explain, predict, understand, and control natural phenomena." Researchers have discovered that children at all ages have misconceptions about many basic scientific concepts which keep them from being scientifically literate (Osborne & Cosgrove, 1983, 1981; Trembath & Barufaldi, 1981).

## Misconceptions

The term "misconceptions" has not been totally accepted as the appropriate nomenclature for students' conceptions which differ from scientists' conceptions. Two major reasons underlie this conflict. First, those who prefer the use of "preconceptions", "naive systems" or "alternative conceptual frameworks," hold that these concepts are a "valid way of thinking" (Fisher & Lipson, 1986) and actually fit into the past historical development of that concept (Prather, 1985). Thus, children's misconceptions may well be valid explanations within the context of their knowledge and their perceptions of what they observe. The second major reason for not using the term "misconception" is that conceptions that differ from those of scientists' today may become scientifically correct tomorrow (Fisher & Lipson, 1986). Concepts are built on theory and new theories develop. Since "misconception" seems to carry a negative connotation, the term misconception will be replaced by the other preferred terms.

Identification of preconceptions is crucial for science educators because normal instruction in proper scientific concepts does not necessarily change these preconceptions (Champagne & Klopfer, 1983; Prather 1985). The "naive systems" with which children enter formal instruction are especially resistant to change (Champagne & Klopfer, 1983). If a teacher does not give the children experiences which make them aware of their preconceptions, they will hold to these "naive systems" in spite of what they are told. Children need in-depth study on basic scientific concepts to bring understanding which will change "naive systems" (Linn, 1987).

Children have a superficial understanding of technical terms which allows them to associate the correct scientific terms with everyday events but renders them incapable of explaining those terms (Osborne & Cosgrove, 1981, 1983). The children's ability to associate the terminology with the event, makes it difficult to determine their degree of understanding and preconceptions through written tests. Clinical interviews which require children to explain these terms are successfully identifying children's preconceptions.

Trembath and Barufaldi (1981) found that the clinical interview was also effective for identifying the "origins" of the preconceptions, ways in which these preconceptions were acquired. During their pilot study, they found that the clinical interview revealed the origins of ninety-nine percent of the preconceptions whereas the Trembath Test of Scientific Misconceptions (TTSM), a written test, revealed the origins of only forty-one percent of the preconceptions (Trembath & Barufaldi, 1981). In their initial investigation they used the TTSM to identify only wrong answers about a few basic concepts and then used the clinical interview to discover the origins, why the children gave the wrong answer, and where they obtained this information. For questions answered incorrectly on the TTSM, participants were asked the following six questions: "1) Did you guess this answer; 2) Did someone tell you this answer; 3) Did you read this somewhere; 4) Did you learn this from television, radio; 5) Is this the result of your own observation; and 6) Did you just work this out for yourself?" (Trembath & Barufaldi, 1981, p.23)

## The Need to Identify Alternative Conceptions for Water Cycle Concepts

One area where children's preconceptions are being identified is in water related concepts (Osborne & Cosgrove, 1981 & 1983; Beveridge, 1985). This identification is important for at least two reasons. First, the concepts involved in regard to water are very basic to the understanding and protection of our environment. Right now there are 1.5 billion people around the world who cannot get safe water. In America alone we have many problems. According to Richard Newman, regional water engineer of New York State's Department of Environmental Conservation, approximately 500 million gallons of untreated sewage is dumped in the Hudson River, the East River and the New York Harbor daily (Licht & Johnson, 1985). This raw sewage is polluting the water. In Maine, "fifty percent of the state's population relies on groundwater wells for drinking water and over one hundred drinking wells have been contaminated in the past year by Leaking Underground Storage Tanks (LUST)" (Truax, 1986, p.24). The noted biologist Joseph Makarewicz believes that "toxic pollution is the most important problem facing the Great Lakes today" (Peterson, 1985, p.17). This becomes significant when one realizes that the Great Lakes are the source of drinking water for over twenty million people (Peterson, 1985). Surveys by the Environmental Protection Agency (EPA) have found that "nearly forty million people - one out of every five Americans - have been drinking water with lead levels higher than EPA's proposed new standard of twenty parts per billion" (Audette, 1987, p. 12). America's aquifers are being poisoned by deepwells which contain fifty-seven percent of the nation's hazardous wastes (Culver & Audette, 1985). Do students know what causes water pollution and how water is purified? "Each year a nation the size of Mexico is added to the world's population" (Harvey, 1988). Do our future generations realize the limitations of our water quantity and quality and the devastating effect a growing population has on both of these? In America the consumption of water has been encouraged which has caused freshwater usage to increase 160 percent between 1955 and 1975 so that each person consumes about 150 gallons a day (Sheaffer, 1984). Sections of our world are experiencing severe drought problems. Record high temperatures have aggravated the drought in the midsection of United States. Cities like San Francisco are rationing water. Lake Michigan is fourteen inches lower than it was a year ago (Harvey, 1988). Do the decision makers of the future have any preconceptions which will cause them to make decisions which will be inappropriate because they were not made aware of their preconceptions?

A second major reason for identifying alternative conceptions for water cycle concepts is that water concepts are common to the elementary science curriculum. The commonality of water concepts in the elementary science curriculum can be determined by a search of textbooks since textbook programs continue to be the primary vehicle for science instruction in elementary-grade classrooms (Meyer, Crummey, & Greer, 1988). Robert Yager (1983) reported that over ninety percent of all science teachers use textbooks ninety-five percent of the time to determine what information will be presented and practiced in their classes. The Association of American Publishers listed the following seven science series as those most used in the schools: Silver Burdett, Holt, Addison, Merrill, Harcourt Brace, DC Heath, and Scott Foresman (Eklund, 1987). The water cycle and water related concepts are found throughout all of these series at the elementary level. If teachers are to effectively teach these concepts, teachers must be informed of the typical preconceptions of children so that their teaching will help students become aware of their preconceptions.

Alternative conceptions are not limited to children. In 1945, M.E. Oakes provided evidence that alternative conceptions exist at all age levels (Ausubel, 1978). Research has shown that high school and college students also possess preconceptions about basic concepts (Sunal, 1982). In fact, older students have views similar to those that young students possess (Osborne & Cosgrove, 1983 and Prather, 1985). In 1982, Clement reported that, even after two semesters of college physics, seventy percent of the subjects in one test group of engineering majors held alternative conceptions (Prather, 1985). Lawrenz (1986) found the existence of preconceptions for physical science concepts among elementary teachers. Other reports suggest that a great majority of society have scientific alternative conceptual frameworks (Prather, 1985). When adults are novices about knowledge, they are greatly affected by their perception (Smith, 1984). People often create their own concepts and weave them into a personalized explanation of natural phenomena.

If preservice teachers have not had their "naive system" changed through meaningful indepth study, they may know the terminology but may have alternative conceptual frameworks of their own. Is it possible that children's naive concepts are created or fostered by teachers with similar preconceptions? Will teachers recognize students' preconceptions as such? It is paramount that preservice teachers' preconceptions be identified. Intervention must take place. The science courses in teacher education programs must gear instruction in such a way that the preservice teachers become aware of their preconceptions. Future teachers' alternative conceptions must be identified in detail in order to provide the specific experiences which will change any "naive systems" they may possess. As teachers become aware of children's preconceptions as well as their own, these teachers may be able to identify their students' preconceptions and provide the appropriate instruction.

Studies have also revealed that students' level of cognitive thinking affects how well they learn certain scientific concepts (Cantu & Herron, 1978). Since most elementary pupils operate at the preoperational or concrete operational level, they will be hindered in their acquisition of science concepts if these concepts are presented in lecture form (Garnett & Tobin, 1984). Lecturing is an abstract means of transmitting information which requires the audience to think at the formal operational level. Considering the preconceptions of students and the importance of the students' cognitive level of thinking, researchers have been advising for some time that teachers of science take on new roles in their classrooms. Simply being information givers will not change students' preconceptions for students will often adjust the new information to fit their preconceptions. Preconceptions can only be disspelled as teachers provide experiences which cause students to become aware of their preconceptions and how their preconceptions differ from the present day scientifically accepted conceptions.

This "new role" can be a threat to elementary teachers. Most elementary teachers say their science preparation was inadequate. In 1980 the National Science Foundation reported only twenty-two percent of elementary teachers felt well qualified to teach science (Zeitler, 1984; Westerback, 1982) compared to nearly two-thirds who felt well qualified to teach reading (Westerback, 1982). There is a number of studies which support the presence of anxiety that preservice teachers express about teaching science (Westerback, 1982).

One reason preservice teachers feel inadequately prepared may be that they are being taught science concepts through an inappropriate cognitive level of reasoning. Most high school and college level courses are taught at the formal operational level. The majority of high school and college students do not operate at the formal operational level (Garnett & Tobin, 1984). In order to adequately train preservice teachers, professors who teach the science content to teacher education students would be wise to use concrete instruction for two reasons. First, most college students do not operate at the formal level and second even formal reasoners learn a new concept better if taught concretely.

## Purpose of Study

The intent of this research is to add to the growing body of information about water cycle concepts. The purpose is to identify the water cycle concepts held by preservice elementary teachers using a structured interview and a paper and pencil multiple choice test. The intent is to determine the relationship between the nature of the preservice elementary school teachers' water cycle conceptual framework and their 1) level of cognitive reasoning, 2) number of high school and college science courses completed, 3) subject matter of high school and college science courses completed, 4) type of university attended, and 5) preferred grade level to teach. A secondary goal is to determine similarities and differences between preservice elementary school teachers' water concepts and upper elementary school children's water concepts.

This study will replicate, in part, studies conducted by Wilson (1988) and McJunkin (1991). Wilson's Water Cycle Assessment Test (WCAT) was used to study elementary children and McJunkin's clinical interview was also used to study elementary children's water cycle concepts. The current study explores preservice elementary teachers concepts of evaporation, condensation, kinetic molecular theory, water treatment, and potable fresh water by using both the WCAT and the clinical interview developed by Wilson and McJunkin respectively.

# Research Questions/Null Hypothesis

The purpose of this study is to answer the questions listed below. The first six questions and related null hypothesis generate the statistical data in this study. Questions 7 and 8 generate the descriptive data.

## Research Question 1 and Ho-1

Question 1. Is there a relationship between the number of science courses preservice elementary school teachers have taken and their water cycle knowledge?

Ho-1. There is no significant relationship between the number of science courses taken by preservice elementary school teachers and the preservice elementary school teachers' mean scores for the Water Cycle Assessment Test.

## Research Question 2 and Ho-2

Question 2. Is there a relationship between the subject of the science courses taken by preservice elementary school teachers and their water cycle knowledge ?

Ho-2. There is no significant relationship between the subject of the science courses taken by preservice elementary school teachers and the preservice elementary school teachers' mean scores on the Water Cycle Assessment Test.

Research Question 3 and Ho-3

Question 3. Is there a relationship between the preservice elementary school teachers' grade level preference for teaching and their water cycle knowledge?

Ho-3. There is no significant relationship between the preservice elementary school teachers' grade level preference for teaching and the preservice elementary school teachers' mean scores on the Water Cycle Assessment Test.

Research Question 4 and Ho-4

Question 4. Is there a difference between the water cycle knowledge of preservice elementary school teachers who attend a large public university compared to those who attend a small private university?

Ho-4a. There is no significant difference between the mean score for the number of specific misunderstandings on the Sound Understanding Interview for preservice elementary school teachers who attend a large public university compared to those who attend a small private university.

Ho-4b. There is no significant difference between the number of correct prerequisite concepts for each question on the Sound Understanding Interview for preservice elementary school teachers who attend a large public university compared to those who attend a small private university.

Ho-4c. There is no significant difference between the mean scores on the Water Cycle Assessment Test for preservice elementary school teachers who attend a large public university compared to those who attend a small private university.

Research Question 5 and Ho-5

Question 5. Is there a relationship between preservice elementary school teachers' water cycle knowledge and their level of cognitive reasoning?

Ho-5a. There is no relationship between the number of correct prerequisite concepts for each question on the Sound Understanding Interview and the preservice elementary school teachers' level of cognitive reasoning on Burney's Logical Reasoning Test.

Ho-5b. There is no relationship between the mean score for the number of specific misunderstandings identified on the Sound Understanding Interview and the preservice elementary teachers' level of cognitive reasoning on Burney's Logical Reasoning Test.

Ho-5c. There is no relationship between the preservice elementary school teachers' mean score on the Water Cycle Assessment Test and the level of cognitive reasoning on Burney's Logical Reasoning Test.

Research Question 6 and Ho-6

Question 6. Is there a difference between the water cycle knowledge of preservice elementary school teachers and upper elementary school children?

Ho-6. There is no significant difference between the mean scores of preservice elementary school teachers and of upper elementary school children on the Water Cycle Assessment Test.

Research Question 7

Question 7. What degrees of understanding do preservice elementary school teachers possess for water cycle concepts?

Research Question 8

Question 8. What are the preservice elementary school teachers' source of water cycle information?

## Definitions

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

1. Alternative Conceptual Frameworks - See misconceptions.

2. Clinical interview - An individual research strategy popularized by Jean Piaget. Individuals are given certain materials and problems to solve. Through observation and questioning, the interviewer clarifies the individual's answers.

3. Concept - "...objects, events, situations or properties that possess common criterial attributes and are designated in any given culture by some accepted sign or symbol." (Ausubel, Novak & Hanesian, 1978, p.89)

4. Concept Formation - "...the critical attributes of the concept are acquired through direct experience, through successive stages of hypothesis generation and testing and generalization ...takes place primarily in young children" (Ausubel, Novak, & Hanesian, 1978, p.56).

5. Concrete Operations - "According to Piaget, the period in the child's mental development ... in which analysis of situations and events is based largely upon present perceivable elements" (Good, 1973, p.553).

6. Degree of Understanding - This is Edmund Marek's (1986, p.38) term which signifies how well students' answers included all the components of a validated answer. Answers that included all the components were classified as "sound understanding." Answers that included at least one component but not all of the components of the validated answer were classified as "partial understanding." Answers that included any component which was not part of the validated answer were classified as "specific misunderstanding." If a student did not give a component (right or wrong), the answer was classified as "no response" (Marek, 1986, p.39).

7. Formal Operations - "According to Piaget, the final stage in mental development of the child in which he is able to use symbols and deal with abstractions" (Good, 1973, p.553).

8. Kinetic Molecular Theory - "The theory that molecules of a gas are in a state of rapid motion, constantly colliding with the walls of any containing vessel and with one another, thereby causing changes in their velocity and direction. Also called kinetic theory of gases" (Good, 1986, p.344).

9. Misconceptions -"...when an incorrect scientific notion has supplied a satisfactory explanantion of a student's experiences, the correct concept, when encountered in formal science instruction, may be disregarded or more likely ... misperceived or distorted by the student so as to fit his existing preconceptions" (Clement, 1982, p.70). "For the person who holds it, a misconception feels like the truth - he doesn't know what he doesn't know" (Eaton, Anderson & Smith, 1983, p.7).

10. Naive Conceptions - "descriptive and explanatory systems for scientific phenomena that develop before they experience formal study of science" (Champagne &

Klopfer, 1983, p.2). "...theories that stand in marked contrast to what students are expected to learn" (Champagne & Klopfer, 1983, p.1).

11. Naive Theories - See naive conceptions.

12. No response - One of the four degrees of understanding. Any one of the responses: I don't know; I don't understand; students merely repeated the question or statement. See Degree of Understanding.

13. Origins of Misconceptions - The source or sourses of information utilized by preservice elementary teachers to answer the questions on the Sound Understanding Interview (Appendix G).

14. Partial Understanding - "...response that includes at least one of the components of the validated answer but not all of the components." See Degree of Understanding.

15. Preconceptions - See Naive Conceptions.

16. Preservice Education - "The academic and professional work in normal school, college, teachers college, or university that a person has done before employment as a teacher" (Good, 1973, p.435).

17. Preservice Elementary School Teacher - Elementary education majors attending a university.

18. Sound Understanding -"... response that includes all components of the validated answer (Appendix B)." See Degree of Understanding.

19. Specific Misunderstanding -"... response that includes irrelevant, illogical, or incorrect information." See Degree of Understanding.

20. Upper Elementary Children - Children who are in the fourth, sixth, and eight grade .

21. Water Cycle - "The cycle by which water evaporates from oceans, lakes, and other bodies of water, forms clouds, and is returned to those bodies of water in the form of rain and snow, the runoff from rain and snow, or ground water. The oceans do

not dry up because when the rain falls, it either drops back into the ocean or sinks into the ground, feeds the streams, and returns to the oceans. We call this process the water cycle." (Good, 1986, p.721).

22. Water Cycle Concepts - Concepts included in this study are evaporation, condensation, groundwater, water/land ratio, gravity, melting, freezing, boiling, steam, water vapor, water pollution, rain, and kinetic molecular theory.

# CHAPTER II

# REVIEW OF SELECTED LITERATURE

## Introduction

The intent of this study is to investigate preservice elementary school teachers' knowledge of the water cycle. A secondary purpose is to compare preservice elementary teachers' knowledge to upper elementary school children's knowledge. Water concepts are basic to an understanding of the environment and the fresh water supply which sustains life. To understand preservice teachers' knowledge of the water cycle includes knowledge of what is scientifically accurate and what is not scientifically accurate. Water cycle misconceptions, considered scientifically inaccurate knowledge, may cause people to make inappropriate decisions about their environment and may prevent them from learning what is accepted as scientifically accurate today. To better understand misconceptions and the misconceptions that exist, a review of literature emphasizing the constructivists' view of learning follows. The constructivists' view was selected for two reasons. First, most of the research on misconceptions was initiated on the constructivists' premise that the naive conceptions which children possess influence what they will learn in school. Second, the constructivists' view supports the need for research to identify alternative conceptions in order to improve science teaching in school. This chapter is divided into four sections:

1) conceptions, 2) misconceptions, 3) children's water cycle alternative conceptions and 4) preservice elementary school teachers.

## Conceptions

### Defining Concepts

In order to understand misconceptions, there needs to be a clear understanding of concepts. Concepts are objects, events, persons or ideas which are grouped together by certain commonalities. Bourne defines a concept as "whenever two or more distinguishable objects or events have been grouped or classified together and set apart from other objects on the basis of some common feature or property characterisitic of each" (Bourne 1966, p.1). For example, the concept of dog. There are certain characteristics that identify a dog. These characteristics determine which animals are dogs. Being an animal is a characteristic of a dog but this characteristic does not distinguish dogs from other animals. As Engelmann states, "a concept is the set of characteristics shared by all those and only those instances in a particular set" (Engelmann, 1969, p.*x* ). Another aspect to consider is that dogs are not exactly alike. There are some characteristics of dogs that can vary and not affect the classification. Dogs can differ in color and shape and still be dogs. Ausubel says it this way: "Concepts themselves consist of the abstracted criterial attributes that are common to a given category of objects, events, or phenomena, despite diversity along dimensions other than those characterizing the criterial attributes shared by all members of the category"(Ausubel, Novak & Hanesian, 1978, p.86). A certain combination of characteristics distinguish a dog from other animals. These characteristics may refer to size, shape, color or use. Color is not a "criterial attribute" of dogs since dogs are different colors. Four legs is a "criterial attribute" but alone it does not distinguish dogs from other four-legged animals such as cats and horses.

Engelmann believes that the context in which a concept is used affects that concept. The discriminating characteristics for the concept of metal used in our everyday lives is very different from the concept of metal used by a laboratory scientist. The novice's concept of metal may not be as advanced as the expert's concept of metal but both are correct conceptions as long as the novice's conception has at least the minimum set of essential discriminations necessary to recognize what is metal and what is not metal (Engelmann, 1969, p.*x*).

Some cognitive scientists have a definite view of the novice and expert. Research has been done on what is called the novice-expert shift. This research distinguishes novices from experts in the following ways. First, novices hold misconceptions. Second, experts see the relationship between the surface features of a problem and the principles which can provide solutions. The novices' structures lack these important relationships; they have a fragmented collection of ideas which are loosely connected (Vosniadou, 1988). Third, experts organize their knowledge in terms of abstract schemata which are not apparent to novices. Fourth, experts' schemata are organized hierarchically while the different levels of the novices' knowledge lack integration (Carey, 1986; Champagne, Klopfer & Gunstone, 1982). As people mature, their concepts are continuously changing and enlarging as they try to make sense of their everyday experience and as they try to incorporate what they are taught (Klausmeier, 1980).

Concepts are the basic building blocks around which people organize their thinking and by which people communicate to others. People organize their thinking by responding to objects and events in terms of categories rather than each object's or event's uniqueness. These categories reduce the complexity of our world by allowing us to place new information in already existing organizations (Joyce & Weil, 1980). If a child does not know what a terrier is, this new information can be organized into his/her existing knowledge by knowing a terrier is a dog. This calls to mind the characteristics of a dog. The only information the child will need to learn are the "criterial attributes" or the combination of characteristics which distinguish a terrier from other dogs rather than learning all the characteristics of terriers.

Concepts make communication with others possible. The mutual understanding gained from concepts provides the basis for verbal interaction.

Concepts can be organized into hierarchies. The concept of animal is more general than the concept dog. The concept terrier is more specific than the concept dog. Categorizing allows using certain cues to identify concepts while ignoring others. These concepts are foundational to higher-level thinking (Arends, 1988). Bruner asserts, "virtually all cognitive activity involves and is dependent on the process of categorizing" (Bruner 1960, p.246).

The constructivists make an important distinction between knowledge (information) and understanding (an individual's organization). Memorization of information which is recalled verbatim but is not incorporated into a student's cognitive structure does not exemplify learning and understanding (Pines & West, 1970) but exemplifies the lack of meaningful learning and understanding (Ausubel, Novak & Hanesian, 1978). Constructivists see "learners as mentally active agents struggling to make sense of their world" (Pines & West, 1986, p.584). Learning is not seen as a process of simply storing pieces of knowledge. "Learners actively construct an individual worldview based upon personal observation and experience and they respond to formal instruction in terms of this preexisting intuitive perspective" (Linn, 1987, p.195).

Forming Concepts

How, then, are concepts developed? Concepts begin to be learned by children at a remarkably early age. First, they learn to distinguish the features of a great variety of objects and events. This discrimination is a precondition to classifying (Gagne', 1977). In 1980 Starkey found that infants between nine and twelve months of age begin object-sorting and object-preference behavior (Arends, 1988, p.325). The ability to distinguish the features of different objects allows chidren to form classes. Starkey (1980) found that by about twenty-six months, children are able to sort objects into simple classifications (Arends, 1988, p.325). Children do not enter school with a "blank slate" (Prather, 1985). Where once teachers assumed that children arrive at school knowing nothing, the "tabula rasa" assumption, we now know that children develop complex concepts before their school years (Mintzes, 1984; Nussbaun, 1979). Children develop these concepts in order to make sense of their world. The knowledge children acquire, Vygotsky refers to as "spontaneous knowledge" (Pines & West, 1986, p.586). This knowledge is acquired in a haphazard manner over a considerable amount of time. As children try to organize information to make sense of their environment, the children's concepts are influenced in several ways. One way is through the interaction of those around them. For example, "Is that (animal who has four legs) a dog?" "No, it is a horse" (Eaton, Anderson & Smith, 1983). Children's concepts are also influenced by everyday language. The concept of sun is influenced by the statement: "Time to get up, the sun is rising." Because everyone knows the importance of oxygen in the air and prevalence of the use of the word oxygen, people make the common error of believing that oxygen is the most common gas in air while in reality nitrogen is the most common (Kuethe, 1963). A third way children's concepts are influenced is by their culture. The attributes of a concept can vary from culture to culture (Pines & West, 1986; Ausubel, Novak, Hanesian,1978).

"The process of learning a new concept is termed concept formation" (Bourne, 1966, p.3). Unlike the Behaviorists orientation which views the learners as passive systems (Bourne, 1966), Constructivists view the learners as active participants in the process of forming concepts (Duit, 1987). Behaviorists contend learners merely register the incoming information. Constructivists see the process of forming concepts as a series of decisions. Learners decide on some tentative hypothesis which may attribute importance to the objects to be categorized. For example, "Dogs are small animals." If this hypothesis is wrong, the learner must decide how to change it. If the hypothesis is correct, is it a "criterial attribute?" Concept formation is looked upon as a sequential decision-making activity. Piaget believes "each person must construct his or her own knowledge" (Joyce & Weil, 1980, p.111). Ausubel says, "Concept formation is characteristic of the preschool child's inductive and spontaneous (untutored) acquisition of generic ideas ( for instance, "house," "dog") from concrete-empirical experience" (Ausubel, Novak & Hanesian, 1978, p.93). Children construct knowledge from concrete experiences when that knowledge is useful. Knowledge is useful if it helps children understand the world around them.

Concept formation occurs as children encounter multiple examples of the concept as well as multiple examples of what is not that concept. The concepts that exist in an individual's mind facilitate the learning of new knowledge if it can be appropriately linked to the existing cognitive structure (Ausubel, 1978).

Piaget would contend that a child must be psychologically ready to receive the concept as well. To Piaget concept formation is the development of schemas. In the beginning a child's schema for "dog" is very broad. As the child acquires new information the schema will change. Schemata become progressively more complex as they are modified by assimilation and accomodation. Assimilation is the process of relating new information to existing cognitive structures. Accomodation is the process of modifying existing cognitive structures (Joyce & Weil, 1980). Piaget contends that schemas develop at a rate governed by physiological maturation. Klausmeier (1980, p.32) disagreed with

Piaget's proposal and believed the research suggests that concepts of successively higher levels are "more a product of learning and experience than of maturation." Consistent with this view Blakemore and Cooper in 1971 found that impoverished environments lead to a lack of brain development (Klausmeier, 1980). But to support Piaget, Epstein in 1978 claimed that the brain grows in spurts. The occurrence of the growth spurts coincide precisely with the ages Piaget has determined for each of his stages (Lawson, 1985). McQueen in 1982 questioned the validity of Epstein's data. Wheatley, Frankland, Mitchell & Kraft in 1978 claimed that the late myelination of the corpus collosum which allegedly occurs at eleven-twelve years old may effect the transition to formal reasoning(Ausubel, Novak, & Hanesian,1978). Olstad and Haury (1984) report that Tipps found that age was the strongest predictor of cognitive level. Maturation does make it possible for higher levels of cognitive reasoning to occur but does not guarantee that individuals will function at those higher levels of reasoning.

Piaget believes maturation occurs in stages. At any given stage one is able to perform certain kinds of thinking. According to Piaget, children's thinking is not logical until the concrete operational stage between the ages of seven to eleven. Children can think logically as they experience the object or action directly. Piaget also contends that before the concrete operational stage, children are not capable of decentration. Children have not developed the intellectual capacity to hold two contradictory ideas in memory at the same time. Without this ability, children cannot see a need to develop a new understanding of the world (Dykstra, 1987). The formal operational stage, from twelve on, no longer needs direct perception nor action to reason logically. At this stage children can reason logically about objects and ideas that do not exist in their experience. They can reason abstractly and therefore are capable of developing abstract schemata. Forming abstract schemata is one distinction between a novice and an expert. Abstractions introduced prematurely seem to cause children to memorize without understanding. Their lack of understanding is concealed by their ability to mouth the termniology (Ausubel, 1978). Studies have shown that formal concepts cannot be understood by students who think at the concrete operational level (Shepherd & Renner 1982, Hewson, 1986; Lawson & Blake, 1976; Tobin & Capie, 1981; Cantu & Herron 1978). Investigations show that a large percentage of adolescents and adults are operating at the concrete operational level (Lawson & Blake, 1976; Saunders & Shepardson 1987; Cantu & Herron 1978). Lawson, Nordland and DeVito (1975) assert that fifty to seventy-five percent of high school and college level students fail to demonstrate formal reasoning on Piagetian type tasks. Shepherd & Renner's (1982) study found seven-three percent of the tenth graders and sixty-six percent of the twelfth graders functioning at the concrete level. In the area of science, research has shown there is a "positive correlation between intellectual development and achievement in science" (Mulopo & Fowler, 1987, p.218) and understanding scientific concepts (Garnett and Tobin, 1984). Piaget believes that children will initiate the learning experiences (spontaneous learning) that optimally match their cognitive structures (Joyce & Weil, 1980). Thus, children's concepts before formal instruction may be compatible, incorrect, inadequate, outdated, and/or unacceptable with principles of modern science. These alternative conceptual frameworks based on intuitive misperceptions, naive inferrences, incorrect logic and/or misinformation constitute a threat to further science education (Prather, 1985).

## Misconceptions

### Reasons For Concerns

Studies document the serious problems that exist in science education today. The National Science Board's report, "Educating Americans for the Twenty-first Century," revealed that science instruction does not prepare students for coping with the problems they will face in this increasing complex world (Linn, 1987). Even though science education has produced individuals who have advanced our technology, medicine, and science knowledge in remarkable ways; science education has not succeeded in producing citizens who understand science concepts so that they can apply that information to the scientific issues that affect their lives. The National Academy of Sciences documented that science curriculum has failed to integrate low-level skills and high-level understanding into the science classes. Without application and understanding, the science information has been neither understood nor remembered (Linn, 1987).

Another evidence of the serious problem in science education is the decline in achievement test scores. For example, achievement test scores for the Scholastic Aptitude Test (SAT) have been declining. The science achievement scores of American students lags behind those from other industrialized countries (Linn, 1987). In regard to the National Assessment for Educational Progress (NAEP) there has been a small but consistent decline in achievement since 1969. Also, there has been a steady decline in the proportion of high school students enrolled in science courses from 1960 to 1977 (Welch, 1979), and in the enrollment in college preparatory science courses (Linn, 1987). In 1979 the National Research Council reported that most school districts were requiring only one year of high school science (Richardson, 1987).

In the mid 1970's researchers began studying misconceptions in the belief that these misconceptions were hindering the learning of science (Champagne & Klopfer, 1983; Confrey, 1987; Helm & Novak, 1983). The unlearning of preconceptions might very well prove to be the most determinative single factor in the acquisition and retention of subject-matter knowledge" (Ausubel, 1978, p.372).

Understanding Misconceptions

A science misconception is a cognitive structure of a concept that does not match the present day scientists' cognitive structure for the concept. There seem to be two strong feelings about misconceptions (Duit, 1987). One belief is that misconceptions are not merely alternate ways of seeing things but errors that must be erased from the mind (Feldsine, 1987). Abimbola (1988) calls this an empiricist's view of students' science knowledge. He bases this connection to the empiricist's view on the idea that a negative view of students' conceptions of science implies that students are empty vessels to be filled with knowledge and the students do not take part in the construction of that knowledge. Abimbola places the terminology used by the empiricist group in two categories. The first category is terms for knowledge that is wrong: "erroneous concepts, misconceptions, misunderstandings, erroneous ideas, and mistakes" (Abimbola, 1988, p.178). The second category is knowledge that is passed down from one generation to another without formal instruction. This information is not considered scientific information. These terms include, "superstitions, unfounded beliefs, folk beliefs, incidental knowledge and world knowledge" (Abimbola, 1988, p.178).

A second belief assumes that misconceptions are children's ways of explaining the world and are "an interesting and valid way of thinking about these processes, in that it meets the needs of students' everyday experiences" (Fisher & Lipson, 1986, p.787). Wandersee (1985, p.581) states "the term misconception is often used to describe an unaccepted (though not necessarily "incorrect") interpretation of a concept by the learner." These proponents would contend that children need to develop their common sense strategies of thinking just like prescientific work preceeded the scientific revolution. Abimbola (1988) would see this as the new philosophy of science called the "conceptual change theory." He sees the terminology for this philosophy divided into two categories.

The neutral connotation category includes terms such as "existing conceptions, prior schemata, prior conceptions." The second category of alternative status between students' existing knowledge and science knowledge include the following terms: "alternative frameworks, alternative ideas, and alternative conceptions" (Abimbola, 1988, p.180). Those who hold to the "conceptual change theory" avoid the use of "misconception" or "errors" to avoid the negative implications of such words. They use terms such as preconceptions, naive theories, and naive notions. These preconceptions are not considered dumb or stupid but are seen as intelligently conceived and quite reasonable. Those who hold the conceptual change theory want children to maintain their intellectual self-confidence. They stress the fact that these naive notions match the ideas which were held as correct by outstanding scientists of the past (Helm & Novak, 1983; Crawley 1988). Preconceptions need not be erased immediately (Prather, 1985; Duit, 1987). These preconceptions are naive or unsophisticated because nothing in the person's experience has challenged these beliefs. Teaching needs to challenge these naive theories.

Abimbola believes that researchers need to develop consistent terminology to represent misconceptions. From his "conceptual change theory" perspective, Abimbola (1988) suggests that "alternative conceptions" be used consistently or if a variety of terms be used that those terms be very well defined.

## Characteristics of Alternative Conceptions

Alternative conceptions seem to have a number of consistent characteristics. One characteristic is that the alternative conceptions are similar to earlier theories in history (Nussbaum & Novick,1982; Ault, 1984; Prather, 1985; Wandersee, 1985; Lawson & Thompson, 1988). There is a number of examples in research. Nussbaum and Novick (1982, p.189) refer to Toulmin who noted that children's understanding of a vacuum matched the old Aristotelian view that "nature abhors a vacuum." Another example of an alternative conception being similar to a theory of the past has to do with the projectile concept. Crawley (1988) explains how preservice elementary teachers' conceptions of projectile is similar to the "impetus theory" created by Philoponus in the sixth century and fully developed by Burdian in the fourteenth century. The concepts that science experts held in the past are now considered a misconception by modern scientists. Expert knowledge is incomplete and rapidly changing. A recent example is in biology and relates to the concept of enzymes. All enzymes were considered proteins until recently when the RNA enzyme, which is not protein, was discovered (Fisher, Lipson & others, 1986).

A second characteristic of alternative conceptions is their resistance to change (Nussbaum & Novick, 1982; Champagne & Klopfer, 1983; Hollon & Anderson, 1986). Alternative conceptions do not automatically accommodate to match the presently scientific conceptions when exposed to formal instruction. Alternative conceptions are not merely isolated facts that can be corrected by providing the appropriate information but they are the actual organization of a cognitive structure. Even if a child accomodates his cognitive structure, the accomodation may only be partial (Nussbaum & Novick 1982). Elements of the previous alternative conception remain a part of the restructured concept (Nussbaum, 1979; Prather, 1985). Or, instead of new cognitive structures being formed (accomodation), the formal instruction is assimilated into the existing structures. The new information is used to support the alternative conception. Instruction may actually make the alternative conception more elaborate and more stable than it was before instruction (Ausubel, Novak & Hanesian, 1978). Those who hold alternative conceptions are characterized by an attitude of certainty; they do not doubt their conceptions. Their alternative conceptions feel like the truth and they do not consider other possibilities. Their answers for solutions to problems based on their alternative conceptions are given quickly and confidently (Gil-Perez & Carrascosa, 1987). For this reason cognitive educators believe that science teaching must begin at the level of the students' alternative conceptions

(Novak, 1987). In order to do this the students' alternative conceptions need to be identified.

A third characteristic of alternative conceptions is their commonality. Many students hold similar incorrect notions (Fisher & Lipson, 1986; Kuethe, 1963). Fisher & Lipson (1986) report that it is not unusual for 40 percent of students to hold similar alternative conceptions. The alternative conceptions are similar irrespective of age, ability or nationality (Champagne & Klopfer 1983).

A fourth characteristic of alternative conceptions is that alternative conceptions are very common during childhood. Ausubel attributes this to three reasons. First, the children's cognitve reasoning is not sophisticated enough and their experiences are limited. Second, inadequate information and/or irrelevant information is accepted into their cognitive structure without scrutiny. Third, words with different meanings than the children understand cause confusion (Ausubel, 1978). If the concept provides a reasonable explanation of the natural phenomena children encounter, they will see no reason to change their notions.

Alternative conceptions are not limited to children. Alternative conceptions are widespread among adolescents and adults despite the science training they received in school (Confrey,1987; Prather 1985). Studies have evidenced that in interviews adults' responses concerning fundamental science concepts are similar to elementary school children (Stephans & Kuehn 1985). For example, Osborne and Cosgrove (1983) report that, in spite of more exposure to instruction, older pupils like younger children view the bubbles in boiling water as air. In relation to their experiences this view appears to them to be logical and sensible. Osborne and Cosgrove (1983) also found that some nonscientific ideas are more popular with adolescents than with younger children. For example, more fifteen year olds believed boiling water changed to oxygen or hydrogen than did twelve year olds. Crawley (1988) found the age of students positively correlated with the number of misconceptions they held.

Alternative conceptions are not limited to the uneducated but are also found among the academically able but scientifically naive (Confrey, 1987). Crawley (1988) reports that even though students with higher grade point averages had alternative conceptions, they had fewer alternative conceptions in both life and physical science than those who had lower grade point averages.

The number of alternative conceptions held by students seems to have a consistent and significant relationship to the reasoning ability . Lawson and Thompson (1981, p.740 - 41) found the percentage of students who did not evidence biological alternative conceptions increased with the increase in reasoning ability (concrete 7.4 percent, transitional 42.2 percent and formal 66.7 percent). Formal operational students hold significantly fewer misconceptions than do concrete operational students (Lawson & Thompson, 1988).

## Sources of Alternative Conceptions

One source of alternative conceptions is that children are perceptually bound (Smith, 1984). What the children perceive determines their concept. Young children can only attend to one factor at a time because their thinking is characterized by centration. This limits their understanding and does not provide a complete picture. Adults who are novices in a domain seemed to be limited to what they see as well (Smith, 1984).

Another source of alternative conceptions is language (Ausubel, Novak & Hanesian, 1978). People take the common everyday meanings of words and attach them to scientific terms. For example, applying the meaning of dominant for dominant people to the scientific term dominant genes (Fisher, Lipson, Miquel & Porter, 1986). Another example: students think of acceleration as speeding up while physicists define acceleration as a change in velocity (Champagne and Klopfer, 1983). Not only does the everyday meanings of words cause alternative conceptions but people do not speak scientifically about natural phenomena. For example, People say, "Let's get some more light on this painting so we can see it." This gives the idea that light illuminates the painting. What should be said is, " Let's get some more light on this painting so more light will reflect off it into our eyes, enabling us to see it better" (Eaton, Anderson and Smith, 1983). Even the everyday language in textbooks and by teachers is misleading (Eaton, Anderson & Smith, 1983).

A third source of alternative conceptions are textbooks and teachers. Concepts that are not considered scientifically accurate today have been presented by both (Duit, 1987). Textbooks and teachers can also be sources of alternative conceptions caused by overgeneralizations and undergeneralizations. If the examples of a concept do not vary sufficiently in noncriterial attributes, a non-distinguishing attribute will be seen as a criterial attribute. For example: if only small dogs are used as examples of dogs, children would not think a Great Dane is a dog. Overgeneralization occurs when a different concept is treated as an example of the concept. An example, using a wolf as an example of a dog. Overgeneralization occurs when the learners do not experience enough nonexamples. Alternative conceptions occur when both overgeneralizations and undergeneralizations occur (Klausmeier, 1980; Ausubel, Novak, & Hanesian, 1978).

A fourth source is religious beliefs. An interesting example of alternative conceptions being formed from religious belief is reported concerning a subject who held the creationist theory. The subject thought there were two separate creations. The first creation included dinosaurs and the second included Adam and Eve (Fisher, Lipson, Miguel & Porter, 1986).

Identification of Alternative Conceptions

Knowing the terminology associated with a scientific phenomenon does not mean students understand the phenomenon itself. Marek (1986) used both an objective test and an interview to test his students understanding of two ecology concepts. The objective test had a typical distribution of grades. But, the interview demonstrated to him that most of the students did not understand the two concepts (Marek, 1986). Researchers have become increasingly skeptical of paper and pencil achievement tests and have sought alternative methods of assessing understanding (Confrey, 1987).

Bar (1987) tested three formats for identifying alternative conceptions: 1) individual oral tests, 2) multiple choice and 3) open-ended written test. She concluded that the multiple choice tests identified the alternative conceptions better than the oral or written tests (Bar, 1987). Students who were more likely to give the right answers in the oral or written could be misled by the scientific sounding answers on the multiple choice. Bar proposed these students were not really sure of their oral and written answers since they could be misled.

Amir, Frankl and Tamir (1987) concluded from their study that carefully constructed multiple choice tests which included alternative conceptions could be used to determine the "frequency" of known alternative conceptions among certain populations. They do not believe multiple choice tests can be used to "identify" alternative conceptions since a large percentage of those who chose the correct answers revealed in their written justification they did not understand and in fact held alternative conceptions.

The most widely used method to identify alternative conceptions is the clinical interview (Alvarez, 1987; Amir, Frankl & Tamir, 1987; Nussbaum 1979). The advantage of this method is the obtaining of in-depth information about students' conceptions. Trembath and Barufaldi (1981) found clinical interviews identified ninety-nine percent of the alternative conceptions while the written method identified forty-one percent. Trembath was particularly concerned that any assessment should give the test taker the opportunity to choose an answer which says, "I don't know."

Studies using the interview method revealed three suggestions that seemed important to remember while giving an interview. Piaget (1960) suggested that interviewers must know how to keep subjects talking freely in the interview without checking or sidetracking their answers. Interviewers must know how to observe and how to be alert to the possible significance of students' answers. Keeping this balance is extremely difficult. Piaget (1960) suggested that if an interviewer felt his/her question had suggested a response than the interviewer should either offer a counter suggestion or probe the answer to see how solid the belief is held. Third, Nussbaum and Novak (1976) concluded from the process of developing their interview that visual props were apt to provide children with cues that would interfere with revealing their spontaneous knowledge.

Cosgrove and Osborne (1981) call their method of interviewing "interview of events." Sometimes this method is referred to as "interview-about-instances" (I.A.I) (Watts & Gilbert 1983). In this type of interview a particular event is demonstrated. An example would be students watch events like water boiling, ice melting, or water condensing. The interviewees are asked to describe what they see and to explain what has happened. They have specific questions for each event and the answers generate additional questions which try to reveal the children's beliefs.

There are drawbacks to using the clinical interview. Because the method is time consuming, usually the sample size is small (Piaget, 1960) and a small sample means the results cannot be generalized to larger groups (Alvarez, 1987).

A second drawback for clinical interviews is representing students' responses so that their answers can be compared (Finley, 1984). Concepts can be expressed in a variety of ways and still be similar. One method used to represent responses is found in

Erickson's study. Erickson (1979) made a transcript of the videotaped interviews. The transcript was used to document the summaries made of the children's notions about heat and temperature. Exerpts from the interview were placed beside the analyst's remarks so the reader could evaluate the analysis of the students' responses (Erickson, 1979). Another method of representing student responses is having students identify concepts and their relationships and then constructing a map-like representation. Feldsine (1987) believes concept maps will not only reveal alternative conceptions but will help students change their alternative conceptions as they see the concepts and their relationship to one another.

Brody (1987) proposes that the clinical interview is a better method to identify alternative conceptions than is the multiple choice. He developed a system which could quantify the students' responses. A certain number of points were given to different levels of understanding. Zero points were given to answers that portrayed no understanding or an alternative conception. Each successively higher level got an additional point. The other levels were: 1) recognized or understood part of the concept, 2) recognized and understood most of the concept and 3) completely understood the concept.

Marek (1986) classified students' responses according to levels of understanding similarly but somewhat different than Brody. He classified the responses but did not give a numerical value as did Brody. Marek used these four classifications: 1) no response (NR), 2) specific misunderstanding (SM), 3) partial understanding (PU) and 4) sound understanding (SU). (See the Definition of Terms section for meanings.) He felt the partial understanding should be divided into degrees of understanding (Marek 1986). According to his study of the food chain, he found a high percentage of students who had specific misunderstandings (57% SM) and a low percentage of students with sound understanding (2% SU).

# Childrens' Water Cycle Alternative Conceptions

There have been a number of studies done on the alternative conceptions children have concerning the concepts involved in the water cycle (Doran, 1972; Erickson, 1979; Cosgrove & Osborne, 1981; Nussbaum & Novick, 1982; Osborne & Cosgrove, 1983; Beveridge, 1985; Finley, 1985; Stephans & Kuehn, 1985; Hollon & Anderson, 1986). This section will consider the alternative conceptions of evaporation, condensation, and the kinetic molecular theory. Throughout the studies on alternative conceptions, researchers noted that children were quick to associate a technical term with an event and often it was the appropriate term but they did not have a sound understanding of those concepts (Cosgrove & Osborne, 1981).

## Evaporation

Most children know when evaporation has taken place (Osborne & Cosgrove, 1983), but they do not think of evaporation as changing from one state of matter to another (Cosgrove & Osborne, 1983). The problem children have with evaporation is knowing what happens to the water. Several studies found children hold these views: 1) the water is absorbed into the container holding the water, 2) the water no longer existed, 3) the water changed to air, and 4) the water molecules split into oxygen and hydrogen (Osborne & Cosgrove, 1983; Beveridge, 1985). The separating of hydrogen and oxygen was only held by older chidren who knew that water molecules have hydrogen and oxygen and these children believe that heat causes water to spit into hydrogen and oxygen (Cosgrove & Osborne,1981). Erickson (1979) found that children think of heat as a substance and believe heat makes things rise. Finley (1985) found that children interchange the terms heat and temperature. They do not distinquish between these terms.

Children have alternative conceptions about boiling water. McJunkin (1991) noted that children do not connect the particulate nature of matter to the process of boiling. Even with considerable prompting by McJunkin, students did not associate the increased movement of molecules with adding heat. Students do not recognize that pressure plays a significant role in boiling a liquid. Students view boiling as an event caused only by heating a liquid (Cosgrove & Osborne, 1981). Another common alternative conception was in identifying the bubbles in boiling water. Osborne and Cosgrove (1983) found that children had four common beliefs about what the bubbles were made of: 1) heat, 2) air, 3) oxygen or hydrogen and 4) steam. This fourth view matches today's scientific view. Steam is a word that does not have a clear definition. Is steam the same as water vapor? Can you see water vapor? Is steam the process of evaporation or condensation? McJunkin (1991) found that elementary students were not sure if steam and water vapor were the same or different. Sixty-six percent of the students did not define water vapor in McJunkin's interview. Students had the same problem with steam and smoke. Children do not seem to understand what steam is. Children think steam is: 1) smoke, 2) air, 3) oxygen and hydrogen or 4) molecules/particles. Many children consider air and steam the same thing. Osborne and Cosgrove (1983) found that children believe the water produced from steam is different water and believe people do not drink steam water.

When Wilson (1988) compared the responses of students' answers on her multiple choice test to students' responses to McJunkin's (1991) interview for fourth, sixth and eighth grade students, she found a significant difference on a question about evaporation. The question was, "What causes wet clothes on a line to dry?" The percentage of students who chose the correct answer on Wilson's test were thirty-five percent for fourth grade, seventy-two percent for sixth grade and seventy-three percent for eighth grade. In McJunkin's interview, none of the students demonstrated a sound understanding of this question and the eighth graders demonstrated the least understanding along with the greatest amount of specific misunderstandings of the three grades. This supports Amir, Frankl & Tamir (1987) who found that students who chose the correct answers on the multiple choice tests also demonstrated lack of understanding and alternative conceptions when they justified their answers in writing.

Condensation

As with evaporation, children can name the process but do not understand condensation. The problem children have with condensation is they do not know where the water comes from. Children hold a variety of views about the source of the water that forms on the outside of a closed jar filled with ice water. One view is that the water goes through the glass. Their justification from personal experience says it sweats like we do. Some children apply the sweating view to rain as well. This will be covered under cloud formation. Other views resulting from instruction cause students to think the water forming on the outside of the glass occurs like diffusion or is the molecules going through the glass. Another view is that the coldness goes through the glass and produces water. The last view is that air changes back to water on a cold surface. Those with formal instruction say the hydrogen and oxygen are reuniting (Cosgrove & Osborne, 1981). Wilson (1988) found that children in fourth, sixth, and eighth grades on taking a multiple choice test had similar misconceptions about the source of the water. The percentage of those choosing answers which were alternative conceptions were sixty-three percent for fourth grade, seventy percent for sixth grade, and fifty-six percent eighth grade. McJunkin (1991) in interviews found that only one student (a fourth grader) out of fifty-seven students from the fourth, sixth and eighth grades had a sound understanding (SU) of where water came from during condensation. Wilson's (1988) multiple choice test (WCAT) revealed that of the three topics (evaporation, condensation and molecular motion), condensation had the lowest score. McJunkin's (1991) interviews revealed that the source of water during condensation had the greatest percentage (78%) of specific misunderstandings and sixth graders had more specific misunderstandings (85%) than fourth or eighth graders. During McJunkin's interviews, not one student used the term condensation. When students were asked to explain condensation, ninety-five percent did not respond (NR).

Piaget (1960) found that children's beliefs about the origins of clouds were very similar to the results found in other countries and these beliefs were influenced by thought characterized by artificialism. Artificialism is a characteristic of preoperational thinking which attributes human or divine creation to everything. Everything that exists is existing because man or God made it. He believes children go through typically three stages in the formation of their beliefs about the formation of clouds. The first stage (five to six year olds) believes clouds are solid and are completely made by man or by God. The second stage (six to nine year olds) believes clouds are formed from chimney smoke. This shows a decrease in artificialism. The last stage (nine to ten year olds) believes clouds are formed by a natural process. Substances are transformed into clouds. The quotes from Piaget's book do not mention that this transformation is the result of kinetic molecular action. Children do say the clouds are condensed substances of air, or moisture, or steam, or heat. Young children do not believe the rain comes from the clouds even though they know the clouds must be present for rain to occur. Piaget (1960) also interviewed children about snow, ice and cold. Young children view cold as a substance. Older children view cold as the absence of heat. At first children believe the cold produces snow and snow produces cold. Later children believe the coldness attracts ice and ice attracts coldness. Often children view cold and air as one in the same thing.

Piaget (1960) interviewed children to discover their beliefs concerning what causes rain. A common belief was that heat caused the clouds to perspire or the sun itself perspired. Stephans & Kuehn (1985) found the same belief.

<u>Kinetic Molecular Theory</u>

The Kinetic Molecular Theory states that all matter is composed of molecules (tiny particles) that are constantly in motion. This theory is not only important for understanding the water cycle but for understanding much of the physical sciences, chemistry and the life sciences. This cannot be a part of children's spontaneous knowledge because they cannot see molecules from their empirical experiences. Shepherd & Renner (1982) found none of the tenth and twelfth graders had a sound understanding (SU) of states of matter and 50percent had specific misunderstandings. Older children hold several common alternative conceptions about molecules. They believe the molecules themselves are hot and cold (Cosgrove & Osborne, 1981; Hollon & Anderson, 1986; Finley, 1985). Children believe the molecules change in size (Doran, 1972). When the children say the molecules expand, they mean the molecules themselves enlarge (Hollon & Anderson, 1986). Children do not believe there is actually empty space between molecules (Doran 1972). Children do not seem to understand kinetic energy. They believe when molecules hit each other, the collisons produce energy (Osborne & Cosgrove, 1983). The friction produces heat (Finley, 1985). Children have trouble internalizing that molecules are constantly moving (Nussbaum & Novick, 1982). Children believe molecules in ice are different than those in liquid or vapor. Molecules in ice do not move (Hollon & Anderson, 1986). Children believe water molecules travel through solids like glass and metal (Finley, 1985).

## Preservice Elementary School Teachers

There are a number of characteristics about preservice elementary teachers that science educators believe are factors which affect the quality of science education in elementary schools (Zeitler, 1984). In this section three of those factors will be covered in relation to teaching the water cycle: 1) science background, 2) level of cognitive reasoning and 3) possession of water cycle alternative conceptions.

### Science Background

It is commonly held that elementary school teachers lack a background in science (Dykstra, 1987). In 1982 Mechling surveyed preparatory programs for elementary teachers and found eight semester hours of science were usually required (Zeitler,1984, p.506). In some of these preparatory programs, geography was considered a science course. If a geography course was part of the eight credit hours, even less content would apply to the science taught in elementary curriculum. Preservice elementary teachers took earth science courses most frequently (mean 1.16) with biological science courses second (mean 0.95) (Zeitler, p.510). Garnett and Tobin (1984) found that preservice teachers with a background in physical sciences were likely to have higher levels of reasoning ability than those who did not. Only eight percent of the preparatory programs required courses in biological, physical and earth sciences (Zeitler, 1984, p.506) Except for biology, advanced courses were seldom taken in any of the sciences (Zeitler, 1984). This means most teachers have not developed depth in any category of science except possibly in biology. Trembath and Barufaldi (1981) found a correlation at the $<.05$ level between the number of alternative conceptions possessed and the number of science credit hours taken at the upper divisions in college. Crawley (1988) found a significant correlation at <.10 level of significance for understanding physical science concepts and the number of college physics courses (<.0526). Boyd (1966) reported no direct relationship between the number of science courses taken by preservice elementary teachers and their ability to correctly identify unfounded beliefs about science in their students.

One reason teacher education programs may not be requiring more science is related to the science requirements for state certification. Franz and Enochs (1982) found twelve states require more than six semester hours, seventeen states require more than zero and up to six semester hours and the remaining states have no formal science requirement for state certification.

The lack of science courses starts earlier than college. For example, high school students in general and not just those who plan to be elementary teachers lack a science background. Herron found in 1977 that secondary students were not choosing to take science courses. Only thirty-one percent had taken a chemistry course and only seventeen percent had taken a physics course (Franz & Enochs, 1982). Contrast this with Wirszup's findings in 1979. Wirszup found ninety-eight percent of the secondary students in the Soviet Union had a solid background in biology, chemistry and physics (Franz & Enochs, 1982, p.287). As for preservice elementary teachers, their mean number of courses taken in high school were as follows: physical sciences 1.17; biological sciences 1.12; earth sciences 0.24; and miscellaneous courses 0.18 (Zeitler, 1984, p.509). Trembath and Barufaldi (1981) found there was no correlation between the number of alternative conceptions held and the total number of semester units of science taken in grades tenth through twelfth nor the number of credit hours taken at lower divisions in college.

With this lack in science background no wonder Franz and Enochs (1982, p.288) report that Weiss' study in 1978 shows that only twenty-two percent of the elementary school teachers feel qualified to teach science while sixty-three percent feel very well qualified to teach reading. Horn and James (1984) found that the percentage of elementary teachers who feel very well qualified to assist other teachers in reading/language arts/ English was 45.5 percent, in social studies and mathematics 22.7 percent and in science 9.1 percent. Teachers do not feel confidant about their understanding of science concepts (Westerback, 1982). On Horn and James' survey (1978), elementary teachers identified what they perceived as factors that affect science instruction in the schools. One of the major factors these teachers identified was that teachers are inadequately prepared to teach science. Zeitler (1984) found that one of the major concerns of preservice elementary teachers who think about teaching science to children is science content.

There are science educators that want to increase the number of science courses required in elementary education programs. Upping the number of courses will not solve the problem. The courses must be taught appropriately. Franz and Enochs (1982) reported the American Association for the Advancement of Science (AAAS) Commision on Science Education's guidelines for appropriate preservice science experiences. The following is a summary of the AAAS's guidelines. Science for elementary teachers should: 1) be taught using open inquiry like the elementary school teachers should teach elementary students, 2) develop an appreciation for science historically, philosophically and practically, 3) develop competence in the processes of scientific inquiry and 4) develop an adequate background for the topics taught in elementary schools.

This research seems to demonstrate that the number of science courses taken in high school and college do not have an influence on alternative conceptions but the number of advanced courses may. Advanced courses provide an indepth study of the subject matter.

## Level of Cognitive Reasoning

Most researchers have used clinical interviews fashioned after Inhelder and Piaget's format to assess formal reasoning (Tobin & Capin, 1981). There are drawbacks to the use of clinical interviews for assessment. The interview is very time consuming. Secondly, the interviewer must be highly qualified in administering the interview (Tobin & Capie, 1981). For these reasons, a number of paper and pencil tests were developed which were not time consuming, would not require an expert administrator, and could be administered to groups.

Tobin and Capie (1981) developed the Test of Logical Thinking (TOLT). The TOLT consists of ten items. Each item requires choosing a correct answer and a correct justification from a number of alternatives (Garnett & Tobin, 1984). The TOLT is easy to administer and score and takes students about thirty-five minutes to complete (Szabo, 1986). The TOLT's reliability coefficient is 0.85 which suggests the test does measure formal thought and may be used in diagnostic assessment. The correlation between performance on clinical interviews described by Inhelder and Piaget and scores on the TOLT were 0.80. The test is suitable for students in grades sixth through college. Ahlawat and Billeh (1987) found the TOLT does not measure conservation of weight and volume as is found in the Piagetian clinical interviews.

Another paper and pencil test that is more involved than the TOLT is Lawson's Classroom Test of Formal Reasoning (TOFR) developed in 1978. In this test each test item involves a demonstration which is used to pose a question. Students choose an answer from the possible solutions listed and explain in writing why they chose that answer (Saunders & Shepardson, 1987). After each demonstration the examiner waits long enough to allow examinees to select an answer and justify their answer before going on to the next item. Enough time is given so that most students can finish but not too much time so that fast students will not get bored. This process makes the test last seventy-five to ninety minutes. To score the justifications, the examiner compares the justifications to Lawson's justifications on his answer sheet (Lawson's test form). Lawson (1983) estimated the reliability of the original to be 0.78. Ahlawat and Billeh (1987) found that the

TOFR does not measure correlational reasoning as is found in the Piagetian clinical interviews.

Another test of formal reasoning is the Arlin Test of Formal Reasoning (ATFR). This test has a high construct validity with clinical interview measures. The ATFR's test-retest reliabilities ranged from 0.76 to 0.89 (Straham, 1986). Santmire's (1985) review of the ATFR states that even with its shortcomings it does assess formal reasoning. The real problem is it is not a good predictor of concrete reasoning because any score above 0 may indicate some formal reasoning.

Studies indicate that science achievement and the understanding of science concepts are related to formal operational reasoning (Cantu & Herron, 1978; Garnett & Tobin, 1984; Fowler & Mulopo, 1987). This presents a problem since studies indicate that the majority of high school and college students (85 percent in the United States) do not function at the formal operational level (Chiapetta, 1976). Even if students are capable of formal reasoning, they usually function at the concrete operational level in science. Sauders & Shepardson (1987) list a number of studies in which assessment showed that more than half of the college students assessed were not formal reasoners. For example, in 1984 Johnson and Barufauldi found 58.5 percent of nursing students were not formal reasoners. Olstad and Havry found fifty-four percent of college students and ninety-six percent of medical students were not formal reasoners. Chiapetta (1976) reports that in 1974 Juraschek found that fifty-two percent of the tested preservice elementary teachers were at the concrete operational level and forty-eight percent at the transitional or formal level. Lawson, Nordland and DeVito (1975) used Piagetian-styled tasks to test the cognitive reasoning of freshman and sophmore preservice elementary teachers. They found eighteen percent were concrete, sixty-six percent were transitional and sixteen percent were formal. Using the Classroom Test of Formal Reasoning, Lawson (1983) assessed the cognitive reasoning levels of preservice elementary teachers who were enrolled in the course Biological Science for the Elementary Teacher. He found 13.75 percent of the preservice elementary teachers were concrete, 57.5 percent were transitional and 28.75 percent were formal. Silverman and Creswell (1982) tested preservice elementary teachers the final semester before student teaching. They found the median for elementary preservice teachers was in the high concrete operational level. Research seems to show that like other college students, preservice elementary teachers are not, as a whole, functioning at the formal operational level. This heightens the possibility that they possess alternative conceptions in science as do many other college students.

## Water Cycle Alternative Conceptions

Lawrenz (1986) gave elementary school teachers a Physical Science Test (PST) and found the teachers knew some of the concepts but not all of them. Fifty percent of the teachers responded correctly to topics like atomic structure, density, heat exchange and others. Seventeen year olds had a mean score of 14 and elementary school teachers had a mean score of nineteen on the PST. Lawrenz felt the answers demonstrated some of the teachers had some alternative conceptions about gases.

Crawley (1988) created the Physical Science Misconceptions Test to identify preservice elementary teachers physical science alternative conceptions. This is a multiple choice test with five choices. Four of the five choices are misconceptions. Seven physical science topics were tested. The topic, states of matter, had the largest percentage of misconceptions (44%) and the topic, heat and temperature, had the fifth largest percentage (33%). The alternative conceptions are similar to children's alternative conceptions. The first similarity is the identification of the bubbles in boiling water. Fifty-seven percent of the preservice elementary teachers identified the bubbles as the oxygen released from the water molecules and twenty-nine percent identified the bubbles as air trapped in the water. A second similarity is the belief that molecules in ice are packed more tightly than in liquid

(53%). A third similarity is temperature is defined as the total heat contained in an object. Forty-seven percent chose this answer (Crawley, 1988).

There is not as much research on the water cycle alternative conceptions which preservice elementary teachers hold compared to studies of elementary school children. But, the research that has been done does show that preservice elementary teachers do have alternative conceptions about the water cycle concepts and that these alternative conceptions are similar to elementary school children's. The question becomes, is there enough known about misconceptions? There is enough known about alternative conceptions if the reason for identification was to develop a theory of learning. There is not enough known about preservice elementary teachers' water cycle alternative conceptions if the goal is to teach water cycle concepts. The teacher needs to know what altenative conceptions the students may possess before the teacher can decide how to teach that lesson (Duit, 1987).

Teachers with alternative conceptions about science concepts are not likely to be able to develop scientifically accurate concepts in their students. In order to help the elementary teachers, alternative conceptions must be identified in preservice elementary teachers so that the preparatory program can begin the conceptual change both by modeling the method and by helping the preservice elementary teachers construct knowledge which is presently accepted by scientists.

## Summary

The review of literature demonstrates that the purpose of this study is important. Elementary teachers play a very important part in helping elementary children understand water cycle concepts. Elementary children are not scientifically knowledgeable about water cycle concepts and in fact they possess many naive conceptions about the water cycle. Studies have shown that these naive conceptions are not easily changed. Preservice teachers must be aware of their own alternative conceptions or they will unknowing pass these on to their students. If preservice elementary teachers' alternative conceptions are similar to children's naive conceptions, preservice teachers will only reinforce the children's naive conceptions. In order to improve science education, it is therefore important to identify what preservice teachers know about the water cycle and whether their knowledge is scientifically accurate

The review of literature has also disclosed the importance of identifying water cycle concepts. Water cycle conceptions are covered throughout the elementary science curriculum. A search of the major science textbook series revealed that water cycle concepts are covered throughout the elementary textbooks and research has shown most teachers use textbook content to determine what is taught in the classroom. In addition to the elementary curriculum, water is a very important part of our environment. We cannot live without water. Many parts of the world are suffering because of the lack of potable water. What better concept could be chosen to develop scientifically literate people whose knowledge of water is used to "explain, predict, understand, and control natural phenomena" (Oickle, 1972).

# CHAPTER III

# DESIGN AND METHODOLOGY

## Introduction

The principal purpose of this chapter is to describe the methods and the procedures followed in conducting this study. Included in this chapter are the descriptions of the sample studied, the descriptions of the instruments used, and the procedures used for collecting and analyzing the data.

## Description of Subjects

Preservice elementary teachers from two universities participated in this study. Preservice elemetary teachers are college or university students who are preparing themselves for professional employment as elementary school teachers.

One university involved in this study was Oklahoma State University (OSU) in Stillwater, Oklahoma. Stillwater is a town of 42,000 located in north central Oklahoma. Oklahoma State has an enrollment of 29,000. The students used for this study were enrolled in three sections of the course titled "Science in the Elementary School Curriculum" during the fall semester of 1988. This pool of subjects was chosen because those taking the course were all preservice elementary teachers. Also, the instructor was willing to use class periods for testing and to give credit to those who had been randomly selected to be interviewed outside of the class period. There were two groups selected from this OSU pool. Group one is called the interviewed group. The interviewed group completed the following:

1) Sound Understanding Interview
2) Questionnaire

3) Wilson's Water Cycle Assessment Test

4) Burney's Logical Reasoning Test

Twenty-seven preservice elementary teachers had been randomly selected to participate in the interview but only twenty-three could be used for analysis. One was unable to attend the interview and three who were interviewed did not take the two tests nor complete the questionnaire.

Group two is called the non-interviewed group. The non-interviewed group was used to see if the interview, which preceded the multiple choice test, would increase the scores on the Water Cycle Assessment Test.The non-interviewed group completed the following:

1) Questionnaire

2) Wilson's Water Cycle Assessment Test

3) Burney's Logical Reasoning Test

Twenty-five students were randomly choosen for analysis from the non-interviewed group by writing all their names on separate slips of paper and drawing twenty-five names. Therefore, forty-eight OSU preservice elementary teachers were used for analysis: the interviewed group of twenty-three and the non-interviewed group of twenty-five.

The second university was John Brown University (JBU) in Siloam Springs, Arkansas. Siloam Springs is located in northwest Arkansas and is a town of about 8500. John Brown is a small private university of about 850 undergraduate students. The student body consists of students from approximately forty-five different states and several foreign countries. All the students who were enrolled in the courses, "Maps and Globes," "Methods in Reading, Elementary," and "Directed Teaching" for the 1989 spring semester participated in this study. The three courses were chosen because the greatest pool of elementary education majors were enrolled. The courses were also chosen because the instructors were willing to take class time for the testing and give credit to those who were randomly selected to be interviewed outside of class. There were two groups selected from this JBU pool. Like the OSU sample, group one is called the interviewed group and completed the same instruments as the OSU interviewed group. Twenty-five preservice elementary teachers were randomly selected for the interviewed group by writing all the names of preservice elementary teachers on separate slips of paper and drawing twenty-five.

Like the OSU sample, group two is the non-interviewed group and completed the same instruments as the OSU non-interviewed group. Twenty-five were randomly chosen for the non-interviewed group by writing all the remaining names of the preservice elementary teachers on separate slips of paper and drawing twenty-five names. Therefore, fifty JBU preservice elementary teachers were used for analysis: twenty-five in the interviewed group and twenty-five in the non-interviewed group.

The combined participants from both universities whose data were analyzed was ninety-eight. Forty-eight were in the interviewed group and fifty were in the non-interviewed group. The fifty non-interviewed subjects were used to determine if the interview had a significant influence on the results of the Water Cycle Assessment Test since the interview preceded the test.

The ninety-eight participants consisted of fourteen freshmen, nine sophmores, thirty-one juniors, thirty-nine seniors and five special students. As for age, 19.4 percent were 17-20 years; 64.3 percent were 20-25; 8.2 percent were 25-30; and 8.2 percent were older than thirty. There were ninety-three females and five males.

## Description of Instruments

Three instruments were used in this study: 1) Sound Understandings Interview, 2) Water Cycle Assessment Test, and 3) Logical Reasoning Test. A questionnaire was used to gather demographic information.

The "Sound Understandings Interview " (SUI) was developed for this study. The SUI is based on the questions used by McJunkin (1991). McJunkin developed questions (Appendix A) for a water concept interview with elementary students by examining previous studies which investigated children's alternative frameworks. The content validity was established by a panel of experts. The following are the questions for the Sound Understanding 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. (Shown a picture of clothes drying on a clothes line.)What causes the clothes to dry?
4. Can we see the water after it leaves the clothes?
5. Can we still call it water?
6. How are clouds formed?
7. How do clouds get up in the sky?
8. What makes it rain?

9. (Shown a jar filled with water and ice.) From where has the water on the outside of the jar come?
10. Is more of the earth's surface covered by water or land?
11. Will we ever run out of good clean water? Why or why not?
12. Where does the bathroom, sink, and toilet water go?
13. How would you get it clean?
14. What is a well?
15. Can you drink from any well?
16. Why can you or can you not drink from any well?
17. Can you drink from any pond, lake, stream, or river? Why or why not?
18. Define evaporation.
19. Define condensation.
20. Define gravity.
21. Define melting.
22. Define boiling.
23. Define freezing.
24. Define ground water.
25. Define steam.
26. Define water vapor.

McJunkin did not ask any questions about wells as do Questions 14 - 16 on the Sound Understanding Interview (SUI). Another difference between the two interviews is Question 13 of the SUI, "How would you get it clean?" McJunkin's study asked this about a pond, lake, stream, or river while the SUI asked it about bathroom, sink, and toilet water.

For each of the twenty-six questions above, a presently scientifically accurate answer had to be produced (Appendix B). The development of these answers were formulated from a variety of sources including books, and college and elementary textbooks (Neiburger, Edinger, & Bonner, 1973; Ucko, 1982; Hill, 1984; etc.)The answer evidenced an appropriate knowledge base for those teaching water related concepts to elementary students rather than an answer that only experts in the field of study would comprehend. Each answer was then broken down into a list of individual prerequisite concepts which when combined produced a complete answer (Appendix B). Both the answer and the list of prerequisite concepts were evaluated by two chemistry professors, two meteorologist professors and a doctoral student in science education. Appropriate changes were made.

An interviewer's recording sheet was also developed (Appendix C). The Sound Understanding Interview (SUI) recording sheet had four parts: 1) Each of the twenty-six questions, 2) A checklist of prerequisite concepts for each question, 3) Two lines titled "other", and 4) Two short lines titled "origin". A question was stated. Under the question was a checklist of prerequisite concepts. After each checklist, there were two lines titled "other" and two lines titled "origin" lines (Appendix C). The following is an example of the format:

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

Heat energy is added ____ origin # ___________

Heat energy becomes molecular kinetic energy ____ _____________

Molecules move faster ____

Molecular attraction is lessened ____

Some fast moving molecules on the surface escape ____

Liquid water becomes water vapor ____

Other___________________________________________________

_________________________________________________________

The following format was used for the Sound Understandings Interview. All interviews were given by the same person. During the interview, the interviewer asked one question at a time and asked the future teachers to give complete and scientifically accurate answers. As in McJunkin's interview of elementary students, an illustration was provided for Questions 1, 2, 3, and 9. The materials for the illustrations included: a ring stand, candle, Pyrex beaker, water, matches, paper towel, hair dryer, picture of clothes drying on clothes line, jar, and ice.

An example for question one is lighting a candle under a container of water. The future teachers were then asked to predict what would happen. The interviewer investigated what the preservice teachers knew about the scientific view of the event. This was done by asking more pointed questions which were generated by the interviewees' responses. As the answers were given, each prerequisite concept indicated was checked on the list. To get all the prerequisite concepts that the interviewees knew, the interviewees were asked to explain more. If the preservice elementary teachers' answers included all the prerequisite concepts on the list, the answers were considered a sound understanding. If some of the concepts were given but not all of them, the answers were considered a partial understanding. If a preservice teacher gave a concept that was not in the list, the answer was considered a specific misunderstanding. This specific misunderstanding was written on the line marked other. If a future teacher said: "I don't know;" merely repeated the question; or did not respond, the answer was identified as no response. Each interview was also taped (auditory) with the consent of the interviewees.

After each answer had been given, these preservice elementary teachers were asked to identify where they perceived they had acquired the information used to answer the question. The interviewees had a list of possible origins (Trembath & Barufaldi, 1981) in front of them. The following is a copy of the list:

What is the source of your information?

1. Did you guess this answer?
2. Did someone tell you this answer sometime?
   Teacher, father, mother, brother, sister
   Other______________________________
3. Did you read this somewhere?
   Book, comic, newspaper
   Other______________________________
4. Did you learn this from television? radio?
5. Is this the result of your own observation?
6. Did you (just) work this out for yourself?

Except for a no response answer, the person chose a source or sources from the list. The number of the sources chosen from the list was written in the space titled origin (Appendix C).

The purpose of the interview was to determine what preservice elementary teachers knew about water concepts. Were their concepts scientific? Without having some possible answers to choose from as they would in a multiple choice test, can they explain the concepts? How were their answers similar or dissimilar to the answers of upper elementary children gave?

The second instrument used was the "Water Cycle Assessment Test" (Appendix F). Wilson (1988) administered this test to fourth, sixth and eight grade students. In this study, the Water Cycle Assessment Test (WCAT) was used to assess preservice elementary teachers' notions of what occurs when water 1) boils, 2) melts, 3) condenses, and 4) evaporates; and also to determine preservice teachers understanding of kinetic molecular motion as applied to water. The reliability coefficient of both the fourth and sixth grade test is .70 and for the eighth grade test is .68 (Wilson, 1988). There are twenty-three multiple choice questions in the Water Cycle Assessment Test. Wilson's study did not include the following question in her research:

Well

a. Deep hole dug into ground water.

b. Deep hole dug into under ground river.

c. Hole dug below water table.

d. Hole dug into clean flowing under ground water.

When the children's WCAT mean score was compared to the preservice elementary teachers' WCAT mean, the WCAT means were based on the twenty-three questions. When the preservice teachers' WCAT mean was compared to the preservice elementary teachers' results on the Sound Understanding Interview and the preservice elementary teachers' demographic information, the mean was based on the twenty-four questions.

The Water Cycle Assessment Test was constructed from the questions used in McJunkin's (1991)water cycle interview. The choices of answers for each WCAT question included the correct answer and optional responses that contained specific misunderstandings as identified during McJunkin's (1991) interviews.

The purpose for using the WCAT was primarily to assess preservice elementary teachers' water cycle knowledge and secondarily to compare the scores of upper elementary children with the scores of preservice elementary teachers. Would these two groups have similar knowledge? Would the preservice elementary teachers demonstrate greater understanding on the interactive interview (SUI) or on the paper and pencil WCAT? Would the WCAT indicate that preservice elementary teachers hold specific misunderstandings? Would these specific misunderstandings be similar to upper elementary children's specific misunderstandings?

The third instrument used was Burney's "Logical Reasoning Test" (1974). This test identifies Piaget's formal stage of cognitive development. Burney's test was used instead of Tobin and Capin's "Test of Logical Thinking" (TOLT) because Burney's test was available for use and similar to the TOLT which was not available. The concurrent validity calculated by the Pearson r for Burney's test with the traditional Piagetian interview tasks is .853. The internal reliablity assessed by the Kuder-Richardson formula 20 is .825. The "Logical Reasoning Test" has twenty-one items containing syllogisms, verbal analogies, questions involving combinatorial and probabilistic reasoning, and questions similar to Piagetian tasks. Fifteen or more correct answers identify formal reasoning, 8-14 correct answers identify the transitional level and seven or less identify concrete reasoning.

The "Logical Reasoning Test" was chosen because it is a paper-and-pencil objective instrument developed to be: 1) given to a group and 2) administered and evaluated by a person with a minimal amount of training. Both of these characteristics were important in the administration of this test. It saved time to be able to administer the test to a large group. It meant the researcher could hand score the test.

The last instrument used was a questionnaire consisting of seventeen demographic questions including : college classification, age, gender, university attending, and more. The questionnaire also asked how many courses the participants took in earth and physical science, chemistry, physics, and biology (Appendix D). Questions about the number and subject matter of science courses taken were asked to see if there was a relationship between the number or subject matter of courses and the preservice elementary teachers' knowledge of the water cycle and related water concepts.

## Procedure

Early in the fall semester of 1988, a pilot study was conducted with five elementary student teachers from John Brown University (fall 1988) and five elementary public school teachers from local schools in Siloam Springs and Gentry, Arkansas. All the participants were given the interview. The pilot study was conducted to discover if questions asked of elementary students (McJunkin, 1991) would cause negative reactions from adults? The only observed reaction was that the adult participants thought they knew the water concepts and became frustrated when they discovered they could not explain the concepts to their satisfaction. A second concern was to determine if the checklist of prerequisite concepts (Appendix C) needed revision. Revisions were made. The revisions were a matter of breaking a lengthy prerequisite concept into two prerequisite concepts. These were divided because interviewees only gave half of the original prerequisite concept. A third concern involved whether the list of prerequisite concepts would be an effective way to record the participants' responses. The list seemed to be effective. The interviews took approximately thirty to forty-five minutes.

The following week half of the pilot group, the student teachers, completed the questionnaire, Water Cycle Assessment Test, and Logical Reasoning Test. The purpose was to determine whether the class period would provide sufficient time to complete the three forms or not. All completed the questionnaire in less than ten minutes. A concern of the student teachers during the completion of the questionnaire involved their uncertainty as to whether a particular course would be considered biology, earth and physical science, physics, or chemistry. Listing suggested courses for earth and physical science was not enough. The Water Cycle Assessment Test was given next. All student teachers finished in eleven minutes. The Logical Reasoning Test was given last and the student teachers were allowed to leave as they completed the test. All but one was done within twenty-five minutes. Therefore, the questionnaire and the two tests could be completed in one class period.

Later in the fall semester of 1988, the study began at OSU. Twenty-six Oklahoma State preservice elementary teachers were interviewed. The interviews were scheduled approximately an hour apart and all twenty-six were accomplished in three consecutive days. The interviews were set to start on Tuesday, since the three sections met on Tuesdays and Thursdays. This made it possible to interview some of the students during the class period by releasing them from class to be interviewed. The remainder were interviewed during the rest of the day or into the evening. The room where the interview took place needed an electrical outlet for the audio taping and the demonstrations, a table for the demonstrations, and a quiet place to avoid distractions. The students who were interviewed were asked not to talk about the interviews until they were told it was all right to do so. This was done to avoid preparing for the interview and subsequent tests.

Two weeks later the generic questionnaire, Wilson's "Water Cycle Assessment Test," and Burney's "Logical Reasoning Test" were administered during one class period, by the same examiner, to the three sections of the course, "Science in the Elementary School Curriculum". The preservice teachers were given the questionnaire first. The questionnaire's answers (1-17) were recorded on a computer sheet. The administrator of the questionnaire encouraged the preservice teachers to ask for clarification if they did not know into which category to list a particular course. The pilot had evidenced difficulty with that part of the questionnaire.

The WCAT was given next. Since the last answer for the questionnaire was number seventeen on the computer sheet, the first WCAT question on the test sheet was numbered eighteen. This numbering was done so that as the examinee read the question and recorded the answer on the computer sheet, the number on the test would correspond with the number on the computer sheet. The OSU computer scored the WCAT.

Since the Logical Reasoning Test took the most time and students completed it in different lengths of time, this was given last. This is not a timed test. Answers were recorded on a scoring sheet to be hand scored to determine the level of cognitve reasoning.

In the spring semester of 1989, twenty-five John Brown preservice elementary teachers were interviewed. The interviews followed the same format and time schedule as did the OSU interviews. Two weeks later, the John Brown sample was given the generic information sheet, Wilson's "Water Cycle Assessment Test," and Burney's "Logical

Reasoning Test." The same person administered the tests in all three classes within that week in the same manner as was done at OSU. The students completed all three of the instruments during their class periods. Three of the students who had been interviewed did not appear on the class testing days so a separate time was set for them.

A difference occurred between the interviews at OSU and JBU on question nine of the SUI. The question reads: From where has the water on the outside of the jar come?" A jar that was dry on the outside was filled with ice water. During the interviews at OSU, the interview room was hot and humid. This caused moisture to form very quickly on the outside of the jar. During the interviews at JBU, the interview room was cool and dry. Sometimes the moisture would not form. The interviewees had to invision what would happen in the summer. All of the interviewees predicted that moisture would form even though some did not get to see it actually happen. Another situation that could have affected the results of the interview was the growing experience of the interviewer. The interviewer became more effective with experience. The interviewer learned to have every term explained by the interviewees used as terms used meant one thing to them and another to the interviewer. For example, "molecules expand." The interviewer thought the interviewee meant the molecules were moving farther and farther apart. But, the interviewee meant the molecules were increasing in size. The meaning of terminology could not be assumed. It was necessary for interviewees to qualify their statements. The first interviews may not have obtained sufficient clarification.

An additional item learned during the study was that a prerequisite was missing in the list of prerequisite concepts for the definition of gravity (SUI question 20). Even though the definition was written in relation to the Earth's gravity and not in relation to other planets or stars, understanding gravity requires knowing the strength of the force. The missing prerequisite was that force is stronger toward the larger body.

After all interviewing and testing had been completed, the interview information was placed in a format that could be quantitatively analyzed. First, each answer was analyzed to determine the degree of understanding. Was the degree of understanding classified as: 1) no response, 2) partial understanding, 3) specific misunderstanding or 4) sound understanding? The degree of understanding was recorded on the computer sheet. If the SUI recording sheet did not have any prerequisite concepts marked nor any specific misunderstandings listed, the answer was recorded on the computer sheet as "no response." If the recording sheet had at least one prerequisite concept checked but not all of the prerequisite concepts and no specific misunderstandings, this was recorded as "partial understanding." If the recording sheet had information recorded on the line marked other, this answer was recorded as a specific misunderstanding even if one or more prerequisite concepts were checked. If all of the prerequisite concepts were checked on the recording sheet and there were no specific misunderstandings, the answer was recorded on the computer sheet as "sound understanding." The interviewer made all these decisions. Some participants' answers did not fit the terminology of the list of prerequisites. This terminology was recorded on the interview sheets. In those cases clarification was increased by listening to the recorded interview. If relistening to the terminology did not bring clarification, John Brown University science professors were used to determine if questionable answers were appropriate or not.

Next, the prerequisite concepts were recorded on the computer sheet. Each prerequisite concept was recorded as a true/false answer. True if given and false if not given. In this way the prerequisite concepts could be analyzed. Which prerequisites were known by the majority of preservice teachers and which were not? Was there a relationship between the prerequisite concepts and courses taken? Between the level of cognitive reasoning?

Specific misunderstandings had to be organized in order to record them for computer analysis. This became difficult because each interviewee had a slightly different way of saying the same thing. This required listening to the segments of the taped conversations whereever specific misunderstandings had been noted on the SUI recording sheet. The specific misunderstandings were classified into similar misunderstandings. For each question only four classifications were chosen for computer analysis. The choice of the four classifications were based on those most frequently given and/or most interesting. All other specific misunderstandings, those not similar to the four classifications were listed as "other" on the computer sheet. The classifications of specific misunderstandings (Appendix E) were checked by two chemistry professors to be sure these were truly considered misunderstandings.

If a preservice teacher answered an interview question, he or she would identify the origin of that information by choosing the source from the origins list (Appendix G). Most participants chose more than one source. Textbooks and teachers were grouped under "school." Fathers, mothers, brothers and other members of the family were grouped under "family." Television and radio were grouped under "TV." Their own observation and working it out for themselves were grouped under "own observation." Any other source was group under "other" with most of these being a guessed answer.

## Data Analysis

An analysis of variance and a *t* test were calculated for the hypotheses 1-6 depending on whether one, two, or more groups were compared. Comparisons were made to describe the relationship between the dependent variable (preservice elmentary school teachers' water cycle scores) and the following independent variables: 1) number of high school and college science courses completed, 2) subject of high school and college science course completed, 3) cognitive reasoning level, 4) type of university attended, 5) grade level preference for teaching, and 6) upper elementary children's water cycle scores. Statistical significance in all tests was predetermined and rejection was set at 0.05 level of significance.

The answers for each question in the Sound Understanding Interview varied in value. The questions had answers that varied from one prerequisite concept to twelve prerequsite concepts. Therefore, each question in the interview (dependent variable) had a mean score which was compared to each independent variable.

# CHAPTER IV

# RESULT

## Presentation of Data

This chapter presents the findings generated from the testing of the hypotheses of the study. In addition, the chapter presents descriptive findings from the questions asked the preservice elementary teachers during the clinical interview on water cycle concepts.

## Statistical Data

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

### Research Question 1 and Ho-1

Question 1. Is there a relationship between the number of science courses preservice elementary school teachers have taken and their water cycle knowledge?

Ho-1 There is no significant relationship between the number of science courses preservice elementary school teachers have taken and the preservice elementary school teachers' mean scores for the Water Cycle Assessment Test.

Results. An analysis of variance was used to measure the relationship between the number of high school and college science courses taken by preservice elementary school teachers and their mean score on the Water Cycle Assessment Test (WCAT). No significant relationship was found at a 0.05 level of significance. Three analyses of variance were calculated: 1) college science courses taken were grouped into three levels: 0-1 course, 2 courses, and 3-7 courses (7 was the highest number taken); 2) high school science courses taken were grouped into five levels: 0-1 course, 2 courses, 3 courses, 4 courses, and 5-8 courses (8 was the highest number taken); and 3) high school and college science courses taken were grouped into five levels: 0-3 courses, 4 courses, 5 courses, 6 courses, and 7-13 courses (13 was the highest number taken). The first analysis of variance based on the number of college science courses grouped into three levels (0-1, 2, & 3-7) calculated a level of significance of 0.09 (df=2, F=2.51). The WCAT multiple choice test has twenty-three items with a perfect score of twenty-three. The WCAT mean score for preservice teachers who had taken 0-1 college science course was 15.72, those who had taken 2 courses was 15.43, and those with 3-7 courses was 16.79 (Table I.). The second analysis of variance based on the number of high school science courses grouped into five levels (0-1, 2, 3, 4, & 5-8) calculated a level of significance of 0.68 (df=4, F=0.58). The WCAT mean score for preservice teachers who had taken 0-1 high school science course was 15.73, those who had taken 2 courses was 15.84, those with 3 courses was 15.25, those with 4 courses was 15.89, and those with 5-8 courses was 16.45 (Table II.). The third analysis of variance based on the total number of science courses taken in high school and college grouped into 5 levels (0-3, 4, 5, 6 & 7-13) calculated a level of significance of 0.28 (df=4, F=1.29). The WCAT mean score for preservice teachers who had taken 0-3 high school and college courses was 15.00, those who had taken 4 courses was 16.26, those with 5 courses was 15.32, those with 6 courses was 16.00 and those with 7-13 was 16.48 (Table III.). On the basis of the three analyses of variance, the null hypothesis is not rejected. The result would seem to say that taking more science courses did not significantly increase the preservice elementary teachers' knowledge of water cycle concepts.

TABLE I

COMPARISON OF THE NUMBER OF COLLEGE SCIENCE COURSES TAKEN AND THE WATER CYCLE ASSESSMENT TEST MEAN SCORE ATTAINED BY PRESERVICE ELEMENTARY SCHOOL TEACHERS

| Number of College Courses | Number of Preservice Teachers | WCAT Mean | Standard Deviation | Minimum Correct | Maximum Correct |
|---|---|---|---|---|---|
| 0-1 | 25 | 15.72 | 2.37 | 11 | 21 |
| 2 | 49 | 15.43 | 2.68 | 9 | 20 |
| 3-7 | 24 | 16.79 | 2.04 | 12 | 20 |

It is interesting to note how many science courses this sampling of preservice elementary school teachers (98) had taken. Table IV indicates the mean number of college science courses taken by these preservice teachers as 2.16. Some preservice teachers had not taken any college science courses and others had taken as many as seven. Table IV indicates the mean number of high school and college science courses taken by preservice teachers as 5.34. Some preservice teachers had not taken any high school or college science courses and others had taken as many as thirteen. Eventually all preservice teachers will take science courses in their college education but an interesting question is how is it that they did not take any science in high school?

TABLE II

COMPARISON OF THE NUMBER OF HIGH SCHOOL SCIENCE COURSES TAKEN AND THE WATER CYCLE ASSESSMENT TEST MEAN SCORE ATTAINED BY PRESERVICE ELEMENTARY SCHOOL TEACHERS

| Number of High School Courses | Number of Preservice Teachers | WCAT Mean | Standard Deviation | Minimum Correct | Maximum Correct |
|---|---|---|---|---|---|
| 0-1 | 15 | 15.73 | 3.65 | 9 | 21 |
| 2 | 25 | 15.84 | 1.85 | 13 | 19 |
| 3 | 20 | 15.25 | 2.36 | 11 | 19 |
| 4 | 18 | 15.89 | 1.78 | 11 | 18 |
| 5-8 | 20 | 16.45 | 2.95 | 9 | 20 |

TABLE III

COMPARISON OF THE NUMBER OF HIGH SCHOOL AND COLLEGE SCIENCE COURSES TAKEN AND THE WATER CYCLE ASSESSMENT TEST MEAN SCORE ATTAINED BY PRESERVICE ELEMENTARY SCHOOL TEACHERS

| Number of Science Courses | Number of Preservice Teachers | WCAT Mean | Standard Deviation | Minimum Correct | Maximum Correct |
|---|---|---|---|---|---|
| 0-3 | 19 | 15.00 | 2.81 | 9 | 21 |
| 4 | 19 | 16.26 | 2.08 | 13 | 20 |
| 5 | 19 | 15.23 | 2.40 | 11 | 19 |
| 6 | 18 | 16.00 | 2.09 | 11 | 19 |
| 7-13 | 23 | 16.48 | 2.83 | 9 | 20 |

TABLE IV

THE AVERAGE NUMBER OF SCIENCE COURSES TAKEN BY PRESERVICE ELEMENTARY SCHOOL TEACHERS

| Level | Number of Preservice Teachers | Mean Number | Standard Deviation | Minimum Number | Maximum Number |
|---|---|---|---|---|---|
| College | 98 | 2.16 | 1.25 | 0 | 7 |
| High School & College | 98 | 5.34 | 2.31 | 0 | 13 |

Research Question 2 and Ho-2

Question 2 Is there a relationship between the subject of the science courses taken by preservice elementary school teachers and their water cycle knowledge?

Ho-2 There is no significant relationship between the subject of the science courses taken by preservice elementary school teachers and the preservice elementary school teachers' mean scores on the Water Cycle Assessment Test.

Results. The *t* tests were calculated to discern if a significant relationship existed between the science course subject and the mean score on the WCAT (Table V). Four *t* tests were calculated: 1) those who had not taken a biology course (M=16.00, SD=1.41) were compared to those who had taken two to six biology courses (M=15.83, SD=2.52), 2) those who had not taken a chemistry course (M=15.15, SD=2.73) were compared to those who had taken one to six chemistry courses (M=16.44, SD=2.12), 3) those who had not taken an earth and physical science course (M=15.69, SD=2.63) to those who had taken one to six earth and physical science courses (M=15.86, SD=2.49), and 4) those who had not taken a physics course (M=15.80, SD=2.65) to those who had taken one to three physics courses (M=16.00, SD=1.59). The *t* test for biology courses resulted in a level of confidence of 0.93. This is not significant at the 0.05 level. The *t* test for chemistry courses resulted in a level of confidence of 0.01. This is significant at the 0.05 level. The *t* test for earth and physical science courses resulted in a level of confidence of 0.82. This is not significant at the 0.05 level. The *t* test for physics courses resulted in a level of confidence of 0.70.This is not significant at the 0.05 level. One of the four*t* tests resulted in a significant relationship between subject and the mean score on the WCAT. There seems to be a significant relationship between taking chemistry courses and the mean score on the Water Cycle Assessment Test. The null hypothesis was not rejected except for the subject of chemistry. There does seem to be a significant relationship between the subject of chemistry and the mean score on the Water Cycle Assessment Test.

TABLE V

COMPARISON OF THE SUBJECTS OF HIGH SCHOOL AND COLLEGE SCIENCE COURSES TAKEN AND THE WATER CYCLE ASSESSMENT TEST (WCAT) MEAN SCORE ATTAINED BY PRESERVICE ELEMENTARY SCHOOL TEACHERS

| Subject and Number of Courses | Number of Preservice Teachers | WCAT Mean | Standard Deviation | Minimum Correct | Maximum Correct |
|---|---|---|---|---|---|
| Biology-(0) | 2 | 16.00 | 1.41 | 15 | 17 |
| Biology-(2-6) | 96 | 15.83 | 2.52 | 9 | 21 |
| Chemistry-(0) | 46 | 15.15 | 2.73 | 9 | 21 |
| Chemistry-(1-6) | 52 | 16.44 | 2.12 | 9 | 20 |
| Earth & Physical Sci.-(0) | 13 | 15.69 | 2.63 | 11 | 21 |
| Earth & Physical Sci.-(1-6) | 85 | 15.86 | 2.49 | 9 | 20 |
| Physics-(0) | 82 | 15.80 | 2.65 | 9 | 21 |
| Physics-(1-3) | 16 | 16.00 | 1.59 | 12 | 18 |

It is interesting to note the type of science courses this sample of ninety-eight preservice elementary school teachers had taken in high school and in college. Table VI indicates the mean number of high school and college biology courses taken as 2.32, earth and physical science 2.10, chemistry 0.73, and physics 0.18. This group of preservice elementary school teachers were far more likely to have taken biology or earth and physical science courses than physics or chemistry courses.

TABLE VI

THE AVERAGE NUMBER OF SCIENCE COURSES, BY SUBJECT, TAKEN IN HIGH SCHOOL AND COLLEGE BY PRESERVICE ELEMENTARY SCHOOL TEACHERS

| Type of Science Course | Number of Preservice Teachers | Average Number | Standard Deviation | Minimum Number | Maximum Number |
|---|---|---|---|---|---|
| Biology | 98 | 2.32 | 0.90 | 0 | 6 |
| Chemistry | 98 | 0.73 | 0.98 | 0 | 6 |
| Earth & Physical Science | 98 | 2.10 | 1.45 | 0 | 6 |
| Physics | 98 | 0.18 | 0.46 | 0 | 3 |

<u>Research Question 3 and Ho-3</u>

Question 3 Is there a relationship between the preservice elementary school teachers' grade level preference for teaching and their water cycle knowledge?

Ho-3 There is no significant relationship between the preservice elementary school teachers' grade level preference for teaching and the preservice elementary school teachers' mean scores on the Water Cycle Assessment Test.

Results. An analysis of variance was calculated to determine if there was a significant relationship between the preservice elementary school teachers' grade level preference for teaching and the preservice elementary teachers' mean score on the WCAT. Preservice teachers who preferred to teach kindergarten through third grade had a WCAT mean score of 15.76. Preservice teachers who preferred to teach kindergarten through sixth grade had a WCAT mean score of 15.42 and those who preferred to teach fourth through sixth grade had a WCAT mean score of 16.22 (Table VII). The analysis of variance resulted in a level of confidence of 0.55 (df=2, F=0.60) which is not at the 0.05 level of significance. The null hypothesis was not rejected. On the basis of this study, the amount of water cycle knowledge which preservice elementary teachers possess does not have a relationship to whether a teacher wants to teach the primary elementary grades or the upper elementary grades.

TABLE VII

COMPARISON OF WATER CYCLE ASSESSMENT TEST MEAN SCORES ATTAINED AND THE GRADE LEVEL PREFERENCE FOR TEACHING STATED BY PRESERVICE ELEMENTARY SCHOOL TEACHERS

| Grade Level Preference | *Number of Preservice Teachers | WCAT Mean | Standard Deviation |
|---|---|---|---|
| K-3 | 50 | 15.76 | 2.50 |
| K-6 | 19 | 15.42 | 2.55 |
| 4-6 | 27 | 16.22 | 2.49 |

*The number does not total 98 because 2 did not indicate a preference.

Research Question 4 and Ho-4

Question 4 Is there a difference between the water cycle knowledge of preservice elementary school teachers who attend a large public university compared to those who attend a small private university?

Ho-4a There is no significant difference between the mean score for the number of specific misunderstandings on the Sound Understanding Interview for preservice elementary school teachers who attend a large public university compared to those who attend a small private university.

Results. A *t* test was used to determine if the difference between the number of specific misunderstandings held by preservice elementary school teachers was significantly different when comparing the type of university the preservice elementary school teacher attended. The university attended was not significant at the level of confidence of 0.38. The small private university's mean score of 11.28 with a standard deviation of 3.74 was not significantly different from the large public university's mean score of 10.39 with a standard deviation of 3.23 (Table VIII) even though the small private university's preservice elementary teachers had a higher average for specific misunderstandings. The null hypothesis was not rejected. On the basis of this study, even though preservice elementary teachers from a small private university possess more specific misunderstandings about the water cycle than those from a large public university, the difference is not significant.

TABLE VIII

THE MEAN NUMBER OF SPECIFIC MISUNDERSTANDINGS IN THE SOUND UNDERSTANDING INTERVIEW OF PRESERVICE ELEMENTARY TEACHERS ATTENDING A SMALL PRIVATE UNIVERSITY AND A LARGE PUBLIC UNIVERSITY

| University | Number of Preservice Teachers | Mean Number | SD | Minimum Number | Maximum Number |
|---|---|---|---|---|---|
| Small Private | 25 | 11.28 | 3.74 | 4 | 18 |
| Large Public | 23 | 10.39 | 3.23 | 5 | 17 |

Ho-4b There is no significant difference between the number of correct prerequisite concepts for each question on the Sound Understanding Interview for preservice elementary school teachers who attend a large public university compared to those who attend a small private university.

Results. A *t* test was used to determine if the difference between the number of prerequisite concepts given for each question on the Sound Understanding Interview was significant when comparing the type of university the preservice elementary school teacher attended. Six of the twenty-six questions showed a significant difference (Table IX). Question 1 (I am going to light this candle under this pan which has water in it . Will anything happen to the water?) resulted in a level of significance of 0.01. Question 3 (What causes the clothes to dry?) resulted in a level of significance of 0.00. Question 4 (Can we see the water after it leaves the clothes?) resulted in a level of significance of 0.04. Question 5 (Can we still call it water?) resulted in a level of significance of 0.01. Question 20 (Define gravity.) resulted in a level of significance of 0.01. Question 23 (Define freezing.) resulted in a level of significance of 0.01. The null hypothesis was not rejected except for six of the twenty-six questions which are given above.

It is interesting to note four of these six questions (Appendix C) specifically refer to evaporation (1, 3, 4, & 5). In the Sound Understanding Interview there are only two other questions that specially refer to evaporation, Questions 2 and 18. Question 2 read, "What will happen to the wet spot?" Question 18 read, "Define evaporation." Table IX indicates that the level of significance for these comparisons were 0.10. Though these are not as significantly different as the other four questions, together this may indicate that preservice elementary teachers from the small private university may know more about evaporation than preservice elementary teachers from the large public university.

TABLE IX

COMPARISON OF THE MEAN SCORE FOR PREREQUISITE CONCEPTS FOR EACH QUESTION IN THE SOUND UNDERSTANDING INTERVIEW FOR PRESERVICE ELEMENTARY SCHOOL TEACHERS ATTENDING A LARGE PUBLIC UNIVERSITY AND A SMALL PRIVATE UNIVERSITY

| Question | Large Public Mean | Small Private Mean | Large Public SD | Small Private SD | PROB>T |
|---|---|---|---|---|---|
| 1 | 1.70 | 2.68 | 1.11 | 1.25 | 0.01 |
| 2 | 1.13 | 1.68 | 1.06 | 1.22 | 0.10 |
| 3 | 0.96 | 2.08 | 0.82 | 1.44 | 0.00 |
| 4 | 1.26 | 1.56 | 0.45 | 0.51 | 0.04 |
| 5 | 0.52 | 1.12 | 0.67 | 0.88 | 0.01 |
| 6 | 0.83 | 1.68 | 1.64 | 2.51 | 0.17 |
| 7 | 0.17 | 0.28 | 0.49 | 0.54 | 0.48 |
| 8 | 1.00 | 1.16 | 1.09 | 1.11 | 0.62 |
| 9 | 1.04 | 1.68 | 0.98 | 1.84 | 0.14 |
| 10 | 1.09 | 1.20 | 0.29 | 0.41 | 0.28 |
| 11 | 2.35 | 2.00 | 1.07 | 1.00 | 0.25 |
| 12 | 1.91 | 2.12 | 1.12 | 1.13 | 0.53 |
| 13 | 2.13 | 2.48 | 1.01 | 1.39 | 0.33 |
| 14 | 1.61 | 1.76 | 1.03 | 1.42 | 0.68 |
| 16 | 2.04 | 2.20 | 1.19 | 1.04 | 0.63 |
| 17 | 2.70 | 2.52 | 1.43 | 1.36 | 0.66 |
| 18 | 0.87 | 1.56 | 1.60 | 1.26 | 0.10 |
| 19 | 0.87 | 1.32 | 0.97 | 1.46 | 0.22 |
| 20 | 1.00 | 1.68 | 0.80 | 0.85 | 0.01 |
| 21 | 0.61 | 1.12 | 1.03 | 0.97 | 0.08 |

TABLE IX (CONTINUED)

| Question | Large Public Mean | Small Private Mean | Large Public SD | Small Private SD | PROB>T |
|---|---|---|---|---|---|
| 22 | 1.91 | 2.40 | 0.95 | 1.00 | 0.09 |
| 23 | 1.96 | 2.68 | 0.98 | 0.95 | 0.01 |
| 24 | 0.83 | 0.96 | 0.72 | 0.84 | 0.56 |
| 25 | 2.09 | 1.68 | 0.95 | 0.80 | 0.11 |
| 26 | 0.48 | 1.08 | 0.85 | 1.44 | 0.08 |

Ho-4c There is no significant difference between the mean scores on the Water Cycle Assessment Test (WCAT) for preservice elementary school teachers who attend a large public university compared to those who attend a small private university.

Results. A *t* test was used to measure the difference between the mean scores on the WCAT for preservice elementary teachers who attend a large public university and those who attend a small private university. The *t* test showed there was a significant difference at 0.01. The large public university's mean score on the WCAT was 15.17 and the small private university's mean score was 16.48 (Table X). The small private university's mean score was significantly higher than the large public university's mean score on the Water Cycle Assessment Test. The null hypothesis was rejected.

TABLE X

COMPARISON OF THE WATER CYCLE ASSESSMENT TEST MEAN SCORES OF PRESERVICE ELEMENTARY SCHOOL TEACHERS FROM A LARGE PUBLIC UNIVERSITY AND FROM A SMALL PRIVATE UNIVERSITY

| University | Number of Preservice Teachers | WCAT Mean | Standard Deviation | Minimum Correct | Maximum Correct |
|---|---|---|---|---|---|
| Large Public | 48 | 15.17 | 2.69 | 9 | 20 |
| Small Private | 50 | 16.48 | 2.13 | 11 | 21 |

Research Question 5 and Ho-5

Question 5 Is there a relationship between preservice elementary school teachers' water cycle knowledge and their level of cognitive reasoning?

Ho-5a There is no relationship between the number of correct prerequisite concepts for each question on the Sound Understanding Interview and preservice elementary school teachers' level of cognitive reasoning on Burney's Logical Reasoning Test.

Results. An analysis of variance was calculated to determine if the difference between the number of correct prerequisite concepts for each question on the Sound Understanding Interview was significant when comparing the preservice elementary school teachers' level of cognitive reasoning using Burney's Logical Reasoning Test. Table XI shows that two of the twenty-six questions had significant levels at 0.05. Question 3 (What causes the clothes to dry?) was 0.0463 (df=2, F=3.29) and question 20 (Define gravity.) was 0.040 (df=2, F=3.46). The remaining questions did not have a significant relationship with the level of cognitive reasoning. With the exception of questions three and twenty, the null hypothesis was not rejected.

TABLE XI

COMPARISON OF THE LEVEL OF COGNITIVE REASONING AND THE MEAN SCORE FOR THE PREREQUISITE CONCEPTS FOR EACH QUESTION INTHE SOUND UNDERSTANDING INTERVIEW

| Question Number | F value | Level of Significance |
|---|---|---|
| 1 | 2.86 | 0.067 |
| 2 | 2.51 | 0.093 |
| 3 | 3.29 | 0.046 |
| 4 | 1.17 | 0.319 |
| 5 | 0.20 | 0.822 |
| 6 | 1.02 | 0.368 |
| 7 | 0.26 | 0.771 |
| 8 | 0.84 | 0.436 |
| 9 | 1.56 | 0.221 |
| 10 | 1.03 | 0.365 |
| 11 | 0.18 | 0.839 |
| 12 | 0.07 | 0.935 |
| 13 | 2.30 | 0.112 |
| 14 | 1.85 | 0.169 |
| 16 | 2.66 | 0.081 |
| 17 | 1.57 | 0.218 |

TABLE XI (CONTINUED)

| Question Number | F value | Level of Significance |
|---|---|---|
| 18 | 1.79 | 0.179 |
| 19 | 1.36 | 0.266 |
| 20 | 3.46 | 0.040 |
| 21 | 2.51 | 0.093 |
| 22 | 1.25 | 0.296 |
| 23 | 2.98 | 0.061 |
| 24 | 0.62 | 0.543 |
| 25 | 1.20 | 0.311 |
| 26 | 1.13 | 0.331 |

An analysis of variance was calculated to measure the relationship between the number of times answers were scored as a partial understanding and the preservice elementary teachers' level of cognitve reasoning. Burney's Logical Reasoning Test identifies three levels of cognitive reasoning: concrete operational, transitional, and formal operational. The Sound Understanding Interview's twenty-six answers are each identified as one of the four types of responses: 1) no response, 2) partial understanding, 3) specific misunderstanding, and 4) sound understanding. For partial understanding responses the concrete reasoners' mean score was 8.50; the transitional reasoners' was 10.73; and the formal reasoners' was 9.71 (Table XII). The level of significance was 0.35 (df=2, F=1.08). Therefore, there was no significant relationship between the mean number of answers that were scored as a partial understanding and the preservice elementary school teachers' level of cognitive reasoning.

TABLE XII

THE MEAN NUMBER OF ANSWERS SCORED AT EACH LEVEL OF UNDERSTANDING ACCORDING TO THE LEVEL OF COGNITIVE REASONING

| Level of Cognitive Reasoning | Number of Preservice Teachers | Partial Understanding Mean | Specific Misunderstanding Mean | Sound Understanding Mean |
|---|---|---|---|---|
| Concrete | 2 | 8.50 | 11.50 | 2.00 |
| Transitional | 15 | 10.73 | 9.47 | 2.00 |
| Formal | 31 | 9.71 | 11.48 | 2.90 |

Ho-5b There is no relationship between the mean score for the number of specific misunderstandings on the Sound Understanding Interview and the preservice elementary school teachers' level of cognitive reasoning on Burney's Logical Reasoning Test.

Results. An analysis of variance was calculated to determine if the difference between the number of answers on the Sound Understanding Interview scored as specific misunderstandings was significant when comparing the preservice elementary school teachers' level of cognitive reasoning using Burney's Logical Reasoning Test. The concrete reasoners' mean score for the number of specific misunderstandings on the Sound Understanding Interview was 11.50; the transitional reasoners' was 9.47; and the formal reasoners' was 11.48 (Table XII). The level of significance was 0.18 (df=2, F=1.78). This level was not significant at 0.05, therefore, the null hypothesis was not rejected.

Ho-5c There is no relationship between the preservice elementary school teachers' mean score on the Water Cycle Assessment Test (WCAT) and the level of cognitive reasoning on Burney's Logical Reasoning Test.

Results. An analysis of variance was calculated to determine if the difference between the WCAT mean score was significant when comparing the preservice elementary school teachers' level of cognitive reasoning. The WCAT mean score for the concrete operational reasoner was 10.40 with the lowest score nine and the highest score fourteen. The WCAT mean score for the transitional reasoner was 15.16 with the lowest score eleven and the highest score twenty. The WCAT mean score for the formal operational reasoner was 16.61 with the lowest score thirteen and the highest score twenty-one (Table XIII). The analysis of variance on the levels of cognitive reasoning WCAT mean scores resulted in a level of significance of 0.0001 (df=2, F=25.46). This is significant at the 0.05 level of confidence. Therefore,the null hypothesis was rejected.The results from testing this hypothesis (Ho-5c) is suspect because of the low number of concrete reasoners' scores.

TABLE XIII

PRESERVICE ELEMENTARY SCHOOL TEACHERS' WATER CYCLE ASSESSMENT TEST MEAN SCORE BY LEVEL OF COGNITIVE REASONING

| Level of Cognitive Reasoning | Number of Preservice Teachers | WCAT Mean | Standard Deviation | Minimum Correct | Maximum Correct |
|---|---|---|---|---|---|
| Concrete | 5 | 10.40 | 2.19 | 9 | 14 |
| Transitional | 31 | 15.16 | 2.31 | 11 | 20 |
| Formal | 62 | 16.61 | 1.93 | 13 | 21 |

Research Question 6 and Ho-6

Question 6 Is there a difference between the water cycle knowledge of preservice elementary school teachers and upper elementary school children?

Ho-6 There is no significant difference between the mean scores of preservice elementary school teachers and of upper elementary school children on the Water Cycle Assessment Test (WCAT).

Results. The WCAT mean score of preservice elementary school teachers was compared to the WCAT mean score of upper elementary children. A perfect score on the WCAT is twenty-three. The WCAT mean score of preservice elementary teachers was 15.84 with the lowest score nine and the highest score twenty-one. The WCAT mean score for upper elementary children was 10.15 with the lowest score 8.95 and the highest score 11.18. An analysis of variance which compared the two WCAT mean scores resulted in a level of significance of 0.0001 (df=1, F=1621.71). This was significant at the 0.05 level of confidence. The null hypothesis was rejected. Deciding to reject the null hypothesis, however, may result in a type II error since the cell sizes were not equal. There were ninety-eight preservice teachers and five hundred thirty-seven upper elementary children used in the comparison.

Even though the WCAT mean scores of preservice elementary teachers are significantly different (higher), a look at Table XIV shows a similar pattern of answers exist between the preservice teachers' answers and the upper elementary children's answers. The answers which were chosen least by preservice elementary teachers were also chosen least by upper elementary children and answers chosen most by preservice elementary teachers were chosen most by upper elementary children.

Table XIV

THE PERCENTAGE OF RESPONSES TO EACH QUESTION IN THE WATER CYCLE ASSESSMENT TEST FOR PRESERVICE ELEMENTARY SCHOOL TEACHERS AND UPPER ELEMENTARY CHILDREN

| | Preservice Elem. Teachers' Answers | | | | Upper Elem. Students' Answers | | | |
|---|---|---|---|---|---|---|---|---|
| WCAT Question Number | % for Answer a | % for Answer b | % for Answer c | % for Answer d | % for Answer a | % for Answer b | % for Answer c | % for Answer d |
| 1 | 0 | 2 | 57 | ***41** | 2 | 7 | 48 | ***43** |
| 2 | 7 | **93** | 0 | 0 | 34 | **62** | 2 | 2 |
| 3 | 42 | **22** | 5 | 31 | 20 | **32** | 28 | 20 |
| 4 | **96** | 2 | 1 | 1 | **63** | 15 | 11 | 11 |

*Bold face print indicates the correct answer for each question.

TABLE XIV (CONTINUED

| | Preservice Elem. Teachers' Answers | | | | Upper Elem. Students' Answers | | | |
|---|---|---|---|---|---|---|---|---|
| WCAT Question Number | % for Answer a | % for Answer b | % for Answer c | % for Answer d | % for Answer a | % for Answer b | % for Answer c | % for Answer d |
| 5 | 22 | 2 | **76** | 0 | 18 | 14 | **56** | 12 |
| 6 | 9 | **88** | 1 | 2 | 34 | **53** | 6 | 7 |
| 7 | 15 | 8 | **48** | 29 | 7 | 7 | **41** | 45 |
| 8 | 13 | 3 | 3 | **81** | 24 | 8 | 30 | **37** |
| 9 | **82** | 7 | 0 | 11 | **45** | 10 | 5 | 39 |
| 10 | **68** | 27 | 1 | 4 | **32** | 39 | 13 | 16 |
| 11 | 7 | 0 | 1 | **91** | 6 | 11 | 22 | **60** |
| 12 | 0 | 0 | **99** | 1 | 6 | 10 | **74** | 9 |
| 13 | 20 | 14 | 60 | **6** | 29 | 21 | 34 | **16** |
| 14 | **84** | 1 | 15 | 0 | **28** | 3 | 61 | 9 |
| 15 | 1 | **96** | 2 | 1 | 11 | **68** | 9 | 11 |
| 16 | **76** | 6 | 5 | 13 | **39** | 16 | 26 | 19 |
| 17 | 16 | 2 | 1 | **81** | 25 | 14 | 9 | **53** |
| 18 | 15 | 17 | 0 | **67** | 18 | 30 | 17 | **35** |
| 19 | 6 | 1 | 2 | **91** | 18 | 10 | 7 | **65** |
| 20 | 74 | 11 | 3 | **12** | 61 | 14 | 7 | **18** |
| 21 | **51** | 1 | 26 | 22 | **38** | 7 | 22 | 32 |
| 22 | 34 | 5 | **60** | 1 | 49 | 11 | **34** | 6 |
| 23 | 10 | 7 | **82** | 1 | 21 | 12 | **46** | 20 |

*Bold face print indicates the correct answer for each question.

## Descriptive Data

This section of the chapter will be more descriptive in nature in order to answer questions not restated as a null hypothesis.

### Research Question 7

Question 7. What degrees of understanding do preservice elementary school teachers possess for water cycle concepts?

Water Cycle Assessment Test (WCAT) Results. One instrument used to answer Question 7 was the Water Cycle Assessment Test (Appendix F.). The entire sample (both the interviewed and non-interviewed group) took the twenty-four item multiple choice test (Wilson,1988, used only 23 items). The mean score of the interviewed group (M=17.25, SD=2.50) was compared to the mean score of the non-interviewed group (M=16.41, SD=2.96) to see if the interview which preceded the WCAT might have a teaching effect on the WCAT scores. The *t* test resulted in a level of significance of 0.24. This result was not significant at the 0.05 level of significance, therefore the interview did not significantly affect the WCAT scores. The remainder of the analysis of the WCAT will be based on the twenty-three questions which Wilson (1988) used in her study. The mean score for the entire sample was 15.84. The highest score was twenty-one and the lowest score was nine. The six questions that the greatest percentage of preservice teachers answered correctly, from the highest percentage to the lowest, were 12, 4, 15, 2, 11, and 19 (Table XIV). Interestingly, all six questions are concerning the concept of evaporation. Turning the questions into statements indicates the scientific knowledge of preservice elementary teachers regarding evaporation.

Question 12: As damp clothes dry, the water goes into the air. (99%)

Question 4: Energy must be added to change water from a liquid to a gas. (96%)

Question 15: Evaporation is changing a liquid to a gas. (96%)

Question 2: The water particles in a pan of water sitting on the hot burner of a stove begin moving faster. (93%)

Question 11: The movement of water particles, the wind and the sun cause wet clothes on a line to dry. (91%)

Question 19: Moving particles speed up and move farther apart during boiling. (91%)

The six questions that the least percentage of preservice teachers answered correctly, from the highest to the lowest, were 13, 20, 3, 1, 7 and 21 (Table XIV). These questions covered a variety of water concepts. Turning the questions into statements indicates the scientific knowledge that is not well known by preservice elementary teachers.

Question 13: Most of the fresh water on the earth is stored as water in ice. (6%)

Question 20: During freezing particles slow down and move farther apart. (12%)

Question 3: The bubbles in boiling water are water vapor. (22%)

Question 1: During evaporation, water goes up into the air as very small bits of water. (41%)

Question 7: For rain to result from a cloud, moisture increases and heat is taken away. (48%)

Question 21: The definition of groundwater is water found underground in porous rock and gravel. (51%)

The Water Cycle Assessment Test revealed some specific misunderstandings. Here are some examples:

Question 1: Water separates into oxygen and hydrogen during evaporation. (57%)

Question 3: The bubbles in boiling water are air (42%) and are oxygen and hydrogen. (31%)

Question 7: For rain to result from a cloud, heat must increase. (15%)

Question 10: Energy must be added to change a liquid to a solid. (27%)

Question 13: Most of the fresh water on the earth is stored as water in the oceans. (60%)

Question 14: If you lived in North America before the white man came, it would be safer to drink the water in a stream which did not have fish, frogs and plants than from a stream that had plants and animals. (15%)

Question 18: Molecular movement decreased during melting. (32%)

Question 20: During freezing particles slow down and get closer together. (74%)

Question 21: Groundwater is water from natural springs. (22%)

Question 22: Steam is defined as "any vapor, fume or mist." (34%)

Sound Understanding Interview Results. The second instrument used to assess preservice elementary school teachers' knowledge of water cycle concepts was the Sound Understanding Interview (Appendix C). Half of the sample (48) was interviewed. Each answer to the twenty-six questions was identified as being one of the four degrees of understanding: no response (NR), partial understanding (PU), specific misunderstanding (SM) and sound understanding (SU). The questions for which the highest percentage of preservice elementary school teachers demonstrated a sound understanding will be described. Table XV indicates Questions 15, 4, 5, and 23 respectively received the highest percentage of sound understanding.

TABLE XV

PERCENTAGE OF RESPONSES ACCORDING TO DEGREES OF UNDERSTANDING FOR ALL QUESTIONS IN THE SOUND UNDERSTANDING INTERVIEW (SUI)

| SUI Question Number | % of No Response | % of Partial Understanding | % of Specific Misunderstanding | % of Sound Understanding |
|---|---|---|---|---|
| 1 | 2 | 44 | 52 | 2 |
| 2 | 19 | 37 | 44 | 0 |
| 3 | 6.5 | 23.5 | 70 | 0 |
| 4 | 0 | 38 | 33 | 29 |
| 5 | 4 | 19 | 52 | 25 |
| 6 | 29 | 19 | 52 | 0 |
| 7 | 40 | 15 | 46 | 0 |
| 8 | 23 | 42 | 35 | 0 |
| 9 | 25 | 47 | 28 | 0 |
| 10 | 0 | 35 | 50 | 15 |
| 11 | 0 | 77 | 23 | 0 |
| 12 | 2 | 77 | 17 | 4 |
| 13 | 0 | 83 | 17 | 0 |
| 14 | 6 | 50 | 29 | 15 |
| 15 | 2 | 0 | 6 | 92 |
| 16 | 6 | 48 | 46 | 2 |
| 17 | 2 | 52 | 46 | 0 |
| 18 | 6 | 33 | 58 | 2 |
| 19 | 27 | 38 | 31 | 4 |
| 20 | 6 | 15 | 67 | 12 |
| 21 | 15 | 62 | 19 | 4 |

TABLE XV (CONTINUED)

| SUI Question Number | % of No Response | % of Partial Understanding | % of Specific Misunderstanding | % of Sound Understanding |
|---|---|---|---|---|
| 22 | 4 | 15 | 79 | 2 |
| 23 | 0 | 52 | 31 | 17 |
| 24 | 10 | 23 | 42 | 25 |
| 25 | 2 | 46 | 48 | 4 |
| 26 | 15 | 13 | 67 | 6 |

Question 15 had the highest percentage of sound understanding responses (92%). The question read, "Can you drink from any well?" Ninety-two percent answered no and six percent answered yes. Though most preservice teachers know that some wells are not safe for drinking, Question 16 reveals they are not well aware of the kinds of pollutants which affect drinking water. The following percentage of preservice teachers identified these types of pollutants: 1) pesticides and/or herbicides 58%, 2) bacteria and/or virus 50%, 3) petroleum 13%, 4) acid rain 10%, and 5) heavy metals 4%. Forty-six percent of the answers for Question 15 contained specific misunderstandings. For example, twenty-seven percent identified minerals as a pollutant. The mineral identified most often was sulfur. Those who gave sulfur believed the sulfur polluted the well water and made the well water unsafe for drinking.

Question 4 had the second highest percentage (29%) of sound understanding responses. The question read, "Can we see the water after it leaves the clothes?" Even though one hundred percent of the preservice teachers answered no, their explanations revealed specific misunderstandings. Thirteen percent of the specific misunderstandings were that the molecules had decreased in size making the molecules so small the water could not be seen. Six percent of the specific misunderstandings were that if the temperature is hot enough, the water can be seen.

Questions 5 and 24 had the next highest percent (25%) of sound understanding responses. Question 5 refers to Question 4 and read, "Can we still call it water?" Fifty-four percent answered yes, but only twenty-nine percent gave the correct explanation that the water was in a gaseous form. Some of the preservice teachers' incorrect explanations were: 1) Water became a different substance such as hydrogen, oxygen, carbon dioxide - 21%. 2) Water was gone - 6%. 3) Molecular structure changed - 10%. 4) Water was no longer water because you cannot feel it -2%. Question 24 asked preservice teachers to define ground water. Twenty-five percent had a "sound understanding" of groundwater. Many preservice teachers expressed being unfamiliar with the term ground water and guessed at the definition. This may explain why thirty-one percent thought groundwater was water on the ground.

The next group of questions are those in which preservice elementary school teachers demonstrated the highest percentage of partial understanding: Questions 13, 11, 12, and 21 (Table XV). Question 13 read, "How would you get water clean?" Eighty-three percent of the answers were identified as partial understanding. Seventy-three percent said adding chemicals to the water is one means. Sending water through a water purification plant was another means suggested by forty-four percent. Many who suggested these means were not aware of the purification process as only thirteen percent suggested filters and/or sedimentation and only four percent suggested bacteria. Twenty-seven percent suggested distillation and/or evaporation as a means of making water purer. This is interesting since buying distilled water is a common and popular occurrence today.

Questions 11 and 12 received the second highest percentage of partial understanding, seventy-seven percent. Question 11 read, "Will we ever run out of good clean water? Why or why not?" Eighty-five percent said we could run out of good clean water, but their understanding of why was incomplete. Only six percent included the fact that the amount of water remains constant. Eighty-three percent realized that pollution may cause the earth to run out of good clean water, while forty percent mentioned the lack of water conservation as a reason for running out of water.

Question 12 read, "Where does bathroom, sink and toilet water go?" The preservice teachers were to suggest all the possibilities they could think of. Sixty-nine percent said, "to a purification plant." Thirty-three percent suggested septic tanks and less than half of those could explain the process that takes place in a septic tank.

Question 21 had the next highest percentage of partial understanding at sixty-two percent. Interviewees were ask to define melting. During their explanation, thirteen percent referred to the increase of kinetic energy even though twenty-seven percent knew that the molecules no longer held their orderly arrangement and thirty-three percent knew that the molecules increased their movement. The term kinetic energy does not seem to be a common term. When preservice teachers were asked what kind of energy is involved in the movement of molecules, most answers were "heat" or "molecular," seldom "kinetic."

The next group of questions will be those in which preservice elementary school teachers exhibited the highest percentage of no response for water cycle concepts. These questions are 7, 6, 19 and 9 (Table XV) and all four of these questions pertain to the concept of condensation. Question 7 had the greatest percentage of no responses at thirty-nine and one half percent. Question 7 is "How do clouds get up in the sky?" None of the preservice teachers' answers were identified as a sound understanding and forty-six percent of the answers contained specific misunderstandings. Three of the forty-eight interviewees demonstrated an alternative conception affected by religious beliefs. Their answer was that God put the clouds up in the sky.

Question 6 had the next highest percentage of no responses at twenty-nine percent. Question 6 asked "How are clouds formed?" None of the answers were identified as a sound understanding and fifty-two percent of the answers contained specific misunderstandings. Two of the most common specific misunderstandings were hydrogen and oxygen were reuniting or hydrogen and carbon dioxide were reuniting.

Question 19 had the next highest percentage of no responses at twenty-seven percent. Question 19 asked for the definition of condensation. Four percent of the answers were identified as sound understanding and thirty-one percent of the answers contained specific misunderstandings.

Question 9 had the next highest percentage of no responses at twenty-five percent. Question 9 read, "From where has the water on the outside of the jar come?" None of the answers were identified as sound understanding and twenty-eight percent of the answers had specific misunderstandings.

The next group of questions will be the questions in which the preservice elementary school teachers exhibited the highest percentage of specific misunderstandings. These questions are 22, 3, 20 and 26 (Table XV). Three of the four questions concern evaporation: 22, 3, & 26. Question 22 had the highest percentage of specific misunderstandings at seventy-nine percent. Question 22 asked preservice teachers to explain boiling. Fifty-four percent believed the bubbles in boiling water were made of air. Fifteen percent believed the bubbles were composed of oxygen. Thirteen percent knew the acceptable answer was that bubbles were composed of water vapor. Eight percent mentioned the part pressure plays when water boils and thirty-eight percent knew the temperature at which water boils. Two percent had a sound understanding of boiling.

Question 3 had the second highest percentage of specific misunderstanding at seventy percent. It read, "What causes the clothes to dry?" A great variety of alternative concepts was revealed. Eight percent believed wind adds energy to molecules and the water becomes hydrogen, oxygen and/or carbon dioxide. Four percent believed the molecules become lighter (weigh less) during evaporation. Thirteen percent believed heat draws moisture. None of the preservice teachers' answers demonstrated a sound understanding of Question 3.

Questions 20 and 26 had the third highest percentage of specific misunderstandings at sixty-seven percent. Question 20 asked preservice teachers to define gravity. Forty-four percent believed there is no gravity in outerspace. This was the most common alternative conception for Question 20. It is possible this percentage could be higher. Not until this alternative concept emerged did the interviewer ask if there is gravity in outer space. Those who believed there is no gravity in outer space gave as their reason, "objects in outer space do not fall to the earth but continue to float in outer space."

Question 26 asked preservice teachers to define water vapor. The most common specific misunderstanding was that water vapor is steam. Thirty-one percent believed water vapor and steam are the same. Perhaps this is the reason for twenty-five percent saying water vapor is visible. Six percent believed water vapor is the result of slow evaporation. Fifteen percent did not answer Question 26 and six percent of the answers evidenced a sound understanding.

To understand what preservice elementary school teachers know about specific concepts involved in the water cycle, the questions pertaining to specific concepts are grouped and discussed in the following categories: condensation, evaporation, kinetic molecular theory, fresh water and water treatment.

Condensation. There are six questions which relate to the concept of condensation in the Sound Understanding Interview (SUI): 6, 7, 8, 9, 19, and 20 (Table XVI) and five questions in the Water Cycle Assessment Test (WCAT): 7, 8, 9, 16 and 17 (Table XVII). Five of the six questions in the SUI related to condensation (6-9 & 19) had the highest percentage of no response of all the SUI's twenty-six questions. When asked to define condensation (Question 19) in the SUI, preservice teachers made comments judged "no response" such as: 1) "I drew a blank on that word." and 2) "I've heard of it, but not sure I can define it." Preservice elementary school teachers are not as familiar with the term and concept of condensation as they are with evaporation. For the WCAT (Table XIV), seven-six percent chose the right answer for the definition of condensation (Question 16) while ninety-six percent chose the right answer for evaporation (Question 15).

TABLE XVI

RESPONSES BY PERCENTAGE TO CONDENSATION QUESTIONS FOR THE SOUND UNDERSTANDING INTERVIEW (SUI)

| SUI Question # | % of Sound Understanding | % of Partial Understanding | % of No Response | % of Specific Misunderstanding |
|---|---|---|---|---|
| 6 | 0 | 19 | 29 | 52 |
| 7 | 0 | 14.5 | 39.5 | 46 |
| 8 | 0 | 42 | 23 | 35 |
| 9 | 0 | 47 | 25 | 28 |
| 19 | 4 | 38 | 27 | 31 |
| 20 | 12 | 15 | 6 | 67 |

None of the preservice elementary school teachers demonstrated a sound understanding for five of the six questions that specifically related to condensation in the Sound Understanding Interview (SUI). Considering the prerequisite concepts of condensation as listed on the SUI (Appendix C), none of the prerequisite concepts are known by the majority of preservice teachers. Even though fifty-four percent of the preservice teachers gave the prerequisite concept -"heat is taken away" during condensation (question 19-prerequisite 2), this was not applied to other questions about condensation. "Heat is taken away" was a prerequisite concept for the question about the formation of clouds (question 6- prerequisite 7) but only nineteen percent gave this prerequisite in their explanation. This prerequisite concept was a part of the explanation of moisture forming on the jar of ice water (question 9 - prerequisite 4) and thirteen percent gave this prerequisite concept. This was supported on the WCAT. Question 7 on the WCAT read, "For rain to result from a cloud, what must occur?" Forty-eight percent answered correctly "add moisture and take away heat." But, twenty-nine percent answered "only add moisture" so temperature was not important and fifteen percent answered "add heat."

TABLE XVII

PERCENTAGE OF CORRECT RESPONSES TO CONDENSATION QUESTIONS FOR THE WATER CYCLE ASSESSMENT TESTS (WCAT)

| WCAT Question # | % Correct for Preservice | % Correct for Children |
|---|---|---|
| 7 | 48 | 41 |
| 8 | 81 | 37 |
| 9 | 82 | 45 |
| 16 | 76 | 39 |
| 17 | 81 | 53 |

The prerequisite concepts on the SUI that were known best were: 1) Gravity brings rain to earth (42%); 2) To rain, air becomes saturated with water (38%); and 3) During condensation, molecular attraction increases (35%).

The SUI prerequisite concepts least known were 1) During condensation, the temperature falls below the dew point (4%) and 2) Clusters of water molecules must be large enough to overcome the updraft (6%). When asked to identify the process of cloud formation, only thirteen percent identified this process as condensation.

From the WCAT, preservice teachers demonstrated that the majority of them did know certain condensation concepts. On Question 8, eighty-one percent knew that the water droplets which formed on the outside of a glass containing a cold drink came from the air. On Question 10, sixty-six percent knew that liquid changes to a solid if energy is taken away. On Question 16, seventy-six percent knew that condensation is changing a gas to a liquid.

Preservice elementary school teachers gave a number of alternative conceptions concerning condensation. The SUI demonstrated specific misunderstandings for all six questions regarding condensation. Of the six questions, Question 9 had the fewest specific misunderstandings with twenty-eight percent and Question 20 had the highest with sixty-seven percent. One common alternative conception is that the hydrogen and oxygen in water molecules separate into hydrogen and oxygen gases during evaporation and reunite during condensation to form water. Answers to Question 6 revealed this alternative conception. Question 6 read, "How are clouds formed?" During the explanation of cloud formation, a preservice teacher said, "Cold air makes the hydrogen and oxygen get back together." Another said, "Don't know, but maybe it would just be the combination of oxygen and hydrogen coming together and forming a cloud." Still another said, "The temperature has dropped and it causes the hydrogen and oxygen to bond and it causes water." A preservice teacher explained how hydrogen and oxygen reunite. "Oxygen has in its outer shell six electrons and its composite is eight...has tendency to want to get eight. Electrons in oxygen pick up two hydrogen and form a large droplet." The following percentage per question indicate the responses that expressed the belief that during evaporation water separates into hydrogen and oxygen: Question 1 - 19%, Question 2 - 13%, Question 3 - 8%, Question 5 - 21%, Question 6 - 15%, Question 8 - 6%, Question 18 - 6% and Question 19 - 6%.

One interviewee's answer to Question 8 referred to a statement she had heard given to children because their thinking is characterized by animism. The interviewee said, "Two little clouds bumping their heads together and crying." She then made this alternative conception more sophisticated by using scientific terms to fit into the explanation and said, "Well, that's pretty close....bumping their heads...actually...is changing the molecules...they become a different substance." The preservice teacher was not sure what change took place. Her guess was that cloud molecules have only one hydrogen molecule and one oxygen molecule and since two hydrogen molecules are needed for water, one hydrogen molecule would "attack" the hydrogen and oxygen molecules causing water to form.

Question 7 had some specific misunderstandings related to condensation. This question asked, "How do clouds get up in the sky?" One specific misunderstanding expressed was, "I would say gravitational pull." Another was, "Clouds don't have gravity to them. There's nothing in them for gravity to push on. They're just air." Even though Question 8 of the interview revealed that forty-two percent of the preservice teachers knew that gravity pulled the clusters of water molecules to the earth, some have alternative conceptions concerning gravity. This was supported in the WCAT. Eight-one percent correctly completed the statement, "Gravity is the force of one object," by choosing "pulling another object," but sixteen percent chose "pushing another object," two percent chose "falling on another object" and one percent chose "moving another object."

Another alternative conception concerning condensation seemed to find its source in the weatherman. Some preservice teachers believed the meeting of a hot and cold front or a high and low pressure system caused "friction" which resulted in rain. The answers to Question 8 revealed this alternative conception. Question 8 read, "What makes it rain?" A preservice teacher answered, "There's a warm air temperature and when a cold air temperature comes in, there's a friction between them and it causes them to clash." Another said, "It's cloudy and if a cold front comes in and causes that friction and sometimes causes it to rain." Another's explanation for what causes it to rain is "The two pressures (high and low) coming together causing friction." Most could not explain what the "friction" does but one said, "Friction stirs up the molecules....molecules take on different form...change from molecules of gas to molecules of liquid...heat caused them to change to water." This last quote revealed another common alternative conception which was that heat caused rain. One preservice teacher said, "Need warm weather or warm air for it to be considered rain. Warm air keeps it in its liquid state. If you have cold weather it's not rain, it's snow." Another said, "Heat has something to do with it because it always happens when it's warm." Question 5 of the WCAT indicates that some preservice teachers believe heat is needed for condensation to take place. Twenty-two percent selected this answer: "If enough heat is added to liquid water, the water condenses."

Question 9 revealed another condensation alternative conception. Preservice teachers believed the molecule itself changed during condensation as well as did its behavior. One view was that molecules change size and weight. A preservice teacher said, "...gas goes to water...when they become smaller...when they get heavy." Another comment was, "Molecules become moist or damp and stick to the side of the jar... makes them small." One used the everyday definition for condense and said, "Particles condense together... it shrinks... makes it less... need to make it small... make particles small." A second view of molecular characteristics was that molecules fill with water. The statement was, "The molecules are all filled up so they can hold no more .. water drops." The third view was that the molecule changed in temperature. Comments like this were made: "...molecules coming together...molecules are getting cooler." It appears that preservice teachers are referring to the temperature (heat energy) of molecules rather than kinetic energy (motion) of molecules.

Question 9 revealed even another alternative conception. Some preservice teachers have a different view of how water forms on the outside of a jar. One view was the water comes through the glass. Some could not explain how. One related the explanation to how the body sweats and said,"Some of the moisture gets through the glass...glass is porous in comparison to the body..when you're too hot it tries to get that equilibrium of temperature so it has to let heat off...sweating." Another interviewee started her explanation in the same way and then said, "Can't literally sweat, cause jar is not living. I'm not sure." In everyday language, we refer to the moisture on the container of a cold drink as "sweat." This may be an example of how the language of a culture can lead to alternative conceptions. A second explanation for the belief that the water came through the glass is an example of how information received in school can provide an explanation for a specific misunderstanding. The explanation is "It was originally in the glass...penetrates through the jar...molecules in the glass are arranged so water can go through it." The interviewee had learned that the glass is made of molecules and there is space between molecules. With this information, she explained that the water molecules leaked through these spaces to the outside of the jar.

The WCAT also demonstrated the existence of this alternative conception. Question 8 on the WCAT read, "Water droplets can form on the outside of a closed jar that contains an ice cold drink. Where do the water droplets come from?" The following are the answers and the percentage of those who chose the answers: three percent chose "through the glass," three percent chose "evaporated over the top of the glass and dripped down the side," eight-one percent chose "air outside the glass" and thirteen percent chose "came from cold water inside the glass."

The WCAT answer, "came from cold water inside the glass," may relate to another alternative conception. "Cold" seemed to be an important distinction. Questions 9 and 19 of the SUI indicated that some preservice teachers believed that cold attracts molecules. One preservice teacher said, "Coldness attracts water in the air." Another said, "I'm going to guess. As the jar got colder and colder, it drew the molecules that are in the air towards it." Still another said, "...through coldness, it draws the molecules to it." They do not consider that the cold decreases the molecular movement but state that the cold attracts molecules.

Evaporation. There are five questions which relate to the concept of evaporation on the Sound Understanding Interview (SUI): 2, 3, 4, 5 and 18 (Table XVIII) and four questions on the Water Cycle Assessment Test (WCAT): 1, 11, 12 and 15 (Table XIX). In the SUI, two of the five questions (4 & 5) are among the top four which had the highest percentage of sound understanding answers for all twenty-six questions (Table XV). On the WCAT, three of the four questions (11, 12 & 15) about evaporation have the highest percentage of correct answers of the twenty-three questions (Table XIV).

TABLE XVIII

RESPONSES BY PERCENTAGE TO EVAPORATION QUESTIONS FOR THE SOUND UNDERSTANDING INTERVIEW (SUI)

| SUI Question # | % of Sound Understanding | % of Partial Understanding | % of No Response | % of Specific Misunderstanding |
|---|---|---|---|---|
| 2 | 0 | 37 | 19 | 44 |
| 3 | 0 | 24 | 7 | 70 |
| 4 | 29 | 38 | 0 | 33 |
| 5 | 25 | 19 | 4 | 52 |
| 18 | 2 | 33 | 6 | 58 |

TABLE XIX

PERCENTAGE OF CORRECT RESPONSES TO EVAPORATION QUESTIONS FOR THE WATER CYCLE ASSESSMENT TEST (WCAT)

| WCAT Question # | % Correct for Preservice | % Correct for Children |
|---|---|---|
| 1 | 41 | 43 |
| 11 | 91 | 60 |
| 12 | 99 | 74 |
| 15 | 96 | 68 |

The prerequisite concepts of evaporation from the SUI showed that more than half of the interviewed preservice teachers knew the following prerequisite concepts: 1) For evaporation to occur, heat energy is added (96%). 2) A source of heat energy is the sun (85%). 3) Heat causes molecules to move faster (65%).

The SUI prerequisite concepts the interviewed preservice teachers knew the least were: 1) Wind increases evaporation by removing the humid air (4%). 2) Increased molecular movement lessens the molecular attraction (6%). 3) Fast moving surface molecules escape first (6%). 4) The movement of molecules is kinetic molecular energy (10%).

Preservice elementary school teachers have a number of alternative conceptions concerning evaporation. The SUI revealed specific misunderstandings for all five questions. Question 4 had the lowest percentage with thirty-three percent and Question 3 the highest with seventy percent (Table XVIII).

A common alternative conception was that evaporation changes water from a liquid to a gas but the gas is not water vapor. The gas or gases may be a variety of gases including hydrogen, oxygen, carbon dioxide, or a combination of these. Though a number of questions revealed this belief, for Question 2 on the SUI a preservice teacher said, "Molecules collide with each other...break apart into hydrogen and carbon dioxide...no longer water." Another said, "Separates the molecules, the atoms of the molecules to hydrogen and oxygen." Still another said, "...collide with each other...break apart into hydrogen and carbon dioxide...no longer water." For Question 4 an interviewee said, "It's (water) in a different form because as it's leaving ...it comes off as oxygen instead of water." This same alternative conception was also noted on the WCAT. Question 1 read, "If a small saucer of water is placed on a window sill in the sunlight, after awhile the saucer will be dry. What happens to the water that was in the saucer?" Fifty-seven percent answered, "It changes into oxygen and hydrogen." Explanations for SUI Question 5 helped explain why fifty-two percent believed the evaporated water could no longer be called water. For example, interviewees said it could not be water because: 1) Water can be seen and this cannot be seen, 2) Water can be felt and this cannot be felt, and 3) Water is a liquid and this is not a liquid.

Another alternative conception for evaporation revealed by the SUI is that the wind increases evaporation by providing energy for the molecules. Question 4 read, "What causes the clothes to dry?" All preservice teachers included the wind, but only four percent knew how the wind helped. Eight percent believed the wind gave the molecules energy. One interviewee expressed it this way, "Along with the sun, it (wind) adds energy to the molecules...it gives them (molecules) energy to move." Others believe the wind blows the molecules into the air.

Another alternative conception was that heat absorbs moisture. An interviewee defined evaporation as, "When heat absorbs the water from the lakes or oceans and it rises up." During the explanation of evaporation for Question 3 of the SUI, an interviewee said, "Heat absorbs the moisture." When asked to explain that statement, the preservice teacher said, "Just soaks it in, I guess."

Another alternative conception was that during evaporation the molecules enlarge and weigh less. One preservice teacher said, "When they're (molecules) small, they're just sitting there not doing anything...so when they're heated and enlarge, they are able to move...they're not as heavy and they're not just stuck...they're not in water form." Another compared the enlarged molecule to a balloon that is blown up and rises in the air. There seemed to be a tendency to believe these enlarged molecules would burst or explode. This would allow the gas or gases to escape. When defining evaporation, a preservice teacher said, "Heat energy changes the molecular structure...it increases the activity within the molecules and evaporates...maybe it causes them to burst...to expand...it becomes lighter." Others mentioned the exploding took place when the molecules collided. The confusion may be based on the fact that hydrogen is a lighter element than is the water molecule. The belief that the water molecule separates into hydrogen and oxygen could explain the belief that the evaporated molecule becomes lighter.

Question 4 read, "Can we see the water after it leaves the clothes?" All those interviewed (48) answered, "No," but thirty-three percent of the explanations revealed specific misunderstandings. Following are the explanations for the water being invisible: 1) The molecules or atoms become too small to be seen (13%). 2) The molecules become invisible (2%). 3) Could see the water if really hot (6%). 4) The molecules are moving too fast to be seen (2%).

Kinetic Molecular Theory. There are six questions which relate to the concept of the state of matter on the Sound Understanding Interview (SUI): 1, 21-23, and 25-26 (Table XX) and eleven questions on the Water Cycle Assessment Test (WCAT): 2-6, 10, 18-20 and 22-23 (Table XXI). On the SUI, none of the six questions appeared among the top percentages for sound understanding. The lowest percentage of the six, was about boiling, two percent for both Question 1 and 22. The WCAT had different results. Three of the eleven questions (2, 4 &19) were among the highest percentages of all correct answers. All three questions were about boiling. It would appear that preservice teachers can choose the correct definiton of a term on a multiple choice test better than they can explain the definition in an interview.

TABLE XX

RESPONSES BY PERCENTAGE TO KINETIC MOLECULAR THEORY QUESTIONS FOR THE SOUND UNDERSTANDING INTERVIEW (SUI)

| SUI Question # | % of Sound Understanding | % of Partial Understanding | % of No Response | % of Specific Misunderstanding |
|---|---|---|---|---|
| 1 | 2 | 44 | 2 | 52 |
| 21 | 4 | 62 | 15 | 19 |
| 22 | 2 | 15 | 4 | 79 |
| 23 | 17 | 52 | 0 | 31 |
| 25 | 4 | 46 | 2 | 48 |
| 26 | 6 | 12 | 15 | 67 |

The prerequisite concepts from the SUI revealed that preservice teachers know that heat makes molecules move faster. Sixty-five percentage gave this prerequisite concept. However, most of the preservice teachers do not seem to be aware that heat energy changes to kinetic energy. Only thirteen percent provided this prerequisite concept. It is possible they are not familiar with the term, "kinetic." The fact that interviewees described the molecules as being hot or cold rather than fast or slow moving, may mean that they do not distinguish between heat energy and the energy of motion. Another evidence of this may be noticed in Question 23. Though eighty-five percent provided prerequisite 1, "Changing from a liquid to a solid requires removing heat," only forty percent mentioned prerequisite 2, "Removing heat, causes the molecules to slow down."

TABLE XXI

PERCENTAGE OF CORRECT RESPONSES TO KINETIC MOLECULAR THEORY QUESTIONS FOR THE WATER CYCLE ASSESSMENT TEST (WCAT)

| WCAT Question # | % Correct for Preservice | % Correct for Children |
|---|---|---|
| 2 | 93 | 62 |
| 3 | 22 | 32 |
| 4 | 96 | 63 |
| 5 | 76 | 56 |
| 6 | 88 | 53 |
| 10 | 68 | 32 |
| 18 | 67 | 35 |
| 19 | 91 | 65 |
| 20 | 12 | 18 |
| 22 | 60 | 34 |
| 23 | 82 | 46 |

Another SUI prerequisite concept well known by preservice teachers was Question 23 (prerequisite 4). Seventy-five percent of the interviewees provided the temperature at which water becomes a solid. Not as many of the interviewed knew at what temperature water boils, Question 22, prerequisite 4. Only thirty-eight percent included this prerequisite in their answer.

Preservice elementary school teachers have some alternative conceptions which relate to the concept of states of matter in addition to those covered in the sections about condensation and evaporation. All six SUI questions concerning states of matter had specific misunderstandings with Question 21 having the least at nineteen percent and Question 22 having the greatest at seventy-nine percent (Table XX). Two of the questions (22 & 26) were among the four questions having the highest percentage of specific misunderstandings. Preservice teachers have some different views about what happens to molecules when water changes from a liquid to a solid or when water freezes. Question 23 read, "Define freezing." During this explanation, eight percent believe the molecules stopped moving entirely when in fact molecules continue to vibrate in a solid. On WCAT Question 20, eleven percent of the entire sample said that during freezing particles stop moving and drift apart. Eight percent believed that molecules expand. Their explanation was that the molecules enlarged rather than the space between the molecules increased. In the interviews, only one correctly stated that when water freezes the molecular movement decreases and the molecules move farther apart. Normally when molecules slow down, the molecules move closer together. Water molecules at freezing move farther apart, the reason ice floats on water rather than sinking. The WCAT revealed the same alternative conception among the entire sample. Question 20 asks for the definition of freezing. Twelve percent chose the correct answer (Table XXI), "Moving particles slow down and move farther apart." Seventy-four percent chose the alternative conception, "Moving particles slow down and get closer together."

Preservice teachers have some alternative conceptions about what happens to molecules when water changes from a solid to a liquid or when ice melts. SUI Question 21 read, "Define melting." One alternative conception given was that the water molecules change. This was expressed in a variety of ways: 1) a chemical reaction occurred, 2) the make-up of the molecules changed, 3) the solid gives off a gas and 4) the heat broke down the particles (molecules). A second alternative conception was that during melting fast moving molecules cause a friction. This friction creates the heat that melts the solid. The molecules themselves create heat. Question 22 about boiling revealed this same belief. An interviewee said, "Molecules are getting faster and faster...start hitting each other and as that happens it gets so hot starts boiling." Another said, "...puts out more energy cause they're (molecules) hitting together."

On the SUI and the WCAT, some preservice teachers demonstrated that they believed "steam" is the result of evaporation rather than condensation. On Question 22 of the WCAT, thirty-four percent of the entire sample chose the answer that defined steam as a vapor. Sixty percent (Table XXI) chose the correct answer: Steam is water in gas form which is condensing. Question 25 of the SUI read, "Define steam." Seventy-three percent of those interviewed gave the prerequisite concept 1, "Evaporation" but only nineteen percent included prerequisite 2, "Water vapor cooled by surrounding air" and only ten percent correctly included prerequisite 3, "Condenses." (Appendix C) Question 26 on the SUI read, "Define water vapor." Thirty-one percent believed that water vapor and steam are the same. Six percent of those interviewed believed that steam requires more heat than does water vapor. One interviewee explained it like this: "Steam is brought on by a large amount of heat while water vapor is pretty much from the room temperature it's around." The belief of this six percent is that boiling produces steam and evaporation produces water vapor.

Water Treatment. There are three questions which relate to the concept of water treatment on the Sound Understanding Interview (SUI): 11, 12 and 13 (TableXXII) and none on the Water Cycle Assessment Test. All three of the questions were among the four highest percentage of "partial understandings" responses.

TABLE XXII

RESPONSES BY PERCENTAGE TO WATER TREATMENT QUESTIONS FOR THE SOUND UNDERSTANDING INTERVIEW (SUI)

| SUI Question # | % of Sound Understanding | % of Partial Understanding | % of No Response | % of Specific Misunderstanding |
|---|---|---|---|---|
| 11 | 0 | 77 | 0 | 23 |
| 12 | 4 | 77 | 2 | 17 |
| 13 | 0 | 83 | 0 | 17 |

Question 11 read, "Will we ever run out of good clean water? Why or why not?" Eighty-five percent of the interviewed answered, "Yes." For one of the reasons why, the most frequently given was pollution (83%). The second most frequent reason given for running out of good clean water was the lack of water conservation (40%). None of the interviewees gave an answer that demonstrated a sound understanding.

Question 12 read, "Where does the bathroom, sink and toilet water go?" Interviewees were encouraged to give any possible destination. The following destinations were mentioned by the following percentage of interviewed preservice teachers: 1) septic tanks - 33%, 2) purification plants - 69% and 3) oceans, lakes, rivers, etc. - 75%. Although some said sewers, they did not know the sewers led to purification plants. Four percent of the interviewed demonstrated "sound understanding" responses.

Question 13 read, "How would you get water clean?" The following is the percentage of interviewees who gave these answers: 1) purification plant - 44%, 2) boiling - 46%, 3) distillation/evaporation - 27% and 4) flowing through the soil and rocks - 23%. None of the interviewees gave an answer that demonstrated sound understanding.

There are a number of prerequisite concepts for water treatment which are not well known by preservice elementary school teachers. For Question 11, six percent of the interviewees' explanation for the possibility of running out of clean water included that the "amount of water remains constant." None of the others mentioned that the world uses the same amount of water over and over again. For Question 12, of the thirty-three percent who knew that sewage might go to a septic tank, only about a third could explain what happened in a septic tank. For Question 13, of the forty-four percent who knew water was cleaned in a purification plant, about a fourth knew what took place to clean the water. Preservice teachers are not well informed about the processes which take place in a purification plant nor in a septic tank.

Preservice elementary school teachers have alternative conceptions for water treatment concepts though a lower percentage of answers contained specific misunderstandings compared to the other water concept categories. Question 11 revealed that fifteen percent believed we would never run out of good clean water. There were two major reasons given for not running out of good clean water: 1) the water cycle is a continuous process and 2) water can always be purified. Question 12 revealed alternative conceptions about septic tanks. Nineteen percent who knew about septic tanks believed everything stays in the tanks and six percent believed the contents of the septic tanks are piped to the sewage plant. Alternative conceptions for Question 13 were given by individuals. One individual thought when unclean water is exposed to the air, the oxygen or carbon dioxide purifies the water. This person was not referring to the process of evaporation. Another individual believed that clean water added to polluted water will make the water purer. A third individual believed that moving water is clean water.

Fresh Water. There are six questions which relate to the concepts of fresh water in the Sound Understanding Interview (SUI): 10, 14-17 (Table XXIII) and 24 and four questions in the Water Cycle Assessment Test (WCAT): 13, 14, 21 and 24 (Table XXIV). In the SUI, two of the six questions (15 & 24) were among the top four questions which had the highest percentage of sound understanding (Table XV). None of the four WCAT questions were among the top five which had the highest percentage of correct answers (Table XIV).

TABLE XXIII

RESPONSES BY PERCENTAGE TO FRESH WATER QUESTIONS FOR THE SOUND UNDERSTANDING INTERVIEW (SUI)

| SUI Question # | % of Sound Understanding | % of Partial Understanding | % of No Response | % of Specific Misunderstanding |
|---|---|---|---|---|
| 10 | 15 | 35 | 0 | 50 |
| 14 | 15 | 50 | 6 | 29 |
| 15 | 92 | 0 | 2 | 6 |
| 16 | 0 | 48 | 6 | 46 |
| 17 | 0 | 52 | 2 | 46 |
| 24 | 25 | 23 | 10 | 42 |

The prerequisite concepts on the SUI regarding fresh water revealed that the following percentage of preservice teachers knew: 1) More of the Earth's surface is covered by water than by land - 100%; 2) Not all wells contain safe drinking water - 92%; 3) Not all lakes, streams, etc. contain safe drinking water - 83%; 4) Bacteria/virus pollute water - 75%; and 5) Pesticides/herbicides pollute water - 58%. In the WCAT, the following percentage of the whole sample chose these correct answers: 1) Ground water is water found underground in porous rock and gravel - 51%. 2) A stream with fish, frogs and plants is safer to drink from than: a sewer; a stream with no fish, frogs and plants; and an ocean- 84%.

TABLE XXIV

PERCENTAGE OF CORRECT RESPONSES TO FRESH WATER QUESTIONS FOR THE WATER CYCLE ASSESSMENT TEST (WCAT)

| WCAT Question # | % Correct for Preservice | % Correct for Children |
|---|---|---|
| 13 | 6 | 16 |
| 14 | 84 | 28 |
| 21 | 51 | 38 |
| 24 | 35 | NA |

In the WCAT, fifty percent chose the correct definition for "ground water" while only twenty-five percent of the interviewees' definitions demonstrated sound understanding on the SUI. On the WCAT Question 24, thirty-five percent chose the correct definition for "well" while on the SUI only fifteen percent of the interviewees' definitions demonstrated sound understanding.

There are prerequisite concepts about fresh water which are not well known by preservice elementary school teachers. The correct prerequisite concepts and the percentage of interviewees who know them are: 1) A well is deeper than the water table - 23%. 2) About seventy-one percent of the Earth's surface is covered by water - 15%. It would appear that some water pollutants are not well known. These pollutants and the percentage of interviewees who did mention them are: 1) heavy metals - 4%; 2) synthetic detergents (phosphates) - 6%; 3) acid rain - 17%; and 4) petroleum - 21%. Question 13 of the WCAT shows that only six percent of the entire sample knew that most fresh water is stored in the form of ice.

Preservice elementary school teachers have alternative conceptions about fresh water. Question 14 read, "What is a well?" The most common alternative conception (10%) about a well is that there must be a pocket of water. One interviewee said, "A hole dug into the ground to find water...like in pockets underneath the earth...can't find just anywhere...must find pockets." Another said, "Wells are from an underground pool." Another said, "I know there are places in the ground where there's water...I would really guess...that there are pockets down under...water perculated down and accumulated." It would appear they thought there must be a pool of water or an aquifer in order to have a well. Question 24 on the WCAT gives more information about this alternative conception. Question 24 asks for the definition of a well. Five percent of the entire sample chose "A deep hole dug into an underground river or lake." Thirty percent of the entire sample chose "A hole dug into clean flowing underground water."

Question 16 asked to explain why you could or could not drink from a well. The most common alternative conception was that minerals pollute the well water (27%). If any particular mineral were mentioned, it was usually sulfur. The interviewer specifically asked if minerals made the water unsafe to drink and the answer was positive. One preservice teacher said, "There's bad minerals...there's sulfur." Another said, "Could be certain types of...maybe, minerals or substances in there." Another said, "Couldn't drink if sulfur or iron in it." Still another said, "Most people don't want to drink sulfur water... I don't think it's very safe...I can't imagine it would be."

Question 17 read, "Can you drink from any pond, lake, stream or river? Why or why not?" An alternative conception was that some preservice teachers (13% of the interviewed) would rather drink from a lake that does not have animals living in it than one that does. Question 14 on the WCAT demonstrated the same belief. It read, "If you lived in North America before the white man came, from which of the following could you most safely drink water?" Fifteen percent chose this answer: "A stream with no fish, frogs and plants" rather than the correct answer (84%), "A stream with fish, frogs and plants." In the interview, the safeness of water seemed to be based on whether the water was clear or not. Based on the results of the SUI and the WCAT, it would appear these preservice teachers believe water is safe to drink if it is clear rather than if pollutants are not present.

## Research Question 8

Question 8. What is the preservice elementary school teachers' source of water cycle information?

After preservice elementary teachers gave a response for a question on the Sound Understanding Interview, they were asked to identify where they had obtained that information. The choices for the source of their information were listed on the origins sheet (Appendix G). Participants were not required to select only one source of information, and some identified more than one source for an answer. Therefore, the combined percentage for each question on Table XXVI is greater than one hundred percent. The major source of water cycle information for preservice elementary school teachers was school. This information category, school, included teachers, textbooks, class activities, and/or any school activity. In twenty-two of the twenty-six questions, the highest percentage of source of information as identified by preservice elementary teachers was school. In the five exceptions (Questions 3, 15, 16, 17, & 24), school was the second most frequently identified source of information. For Question 3 (What causes the clothes to dry?), Questions 15 and 16 (Can you drink from any well? Why?), and Question 17

(Can you drink from any pond, lake, stream or river? Why or why not?) the highest percentage of source of information identified by perservice teachers was their "own observation" (Table XXV). For Question 24 (Define ground water.) the highest percentage of source of information identified by preservice elementary teachers was "other." "Other" chiefly consisted of guessing the answer.

TABLE XXV

PERCENTAGE OF RESPONSES TO SOURCES OF INFORMATION FOR EACH QUESTION IN THE SOUND UNDERSTANDING INTERVIEW (SUI)

| Question Number | % for School | % for Family | % for TV | % for Own Observation | % for Other |
|---|---|---|---|---|---|
| 1 | 88 | 6 | 0 | 25 | 13 |
| 2 | 42 | 6 | 0 | 31 | 29 |
| 3 | 50 | 2 | 0 | 54 | 21 |
| 4 | 69 | 0 | 0 | 25 | 13 |
| 5 | 63 | 2 | 4 | 17 | 19 |
| 6 | 56 | 0 | 6 | 2 | 23 |
| 7 | 33 | 2 | 0 | 15 | 23 |
| 8 | 60 | 4 | 10 | 8 | 13 |
| 9 | 40 | 2 | 0 | 38 | 19 |
| 10 | 85 | 2 | 0 | 2 | 15 |
| 11 | 52 | 6 | 40 | 19 | 23 |
| 12 | 42 | 10 | 33 | 21 | 33 |
| 13 | 52 | 10 | 21 | 25 | 44 |

TABLE XXV (CONTINUED)

| Question Number | % for School | % for Family | % for TV | % for Own Observation | % for Other |
|---|---|---|---|---|---|
| 14 | 40 | 15 | 2 | 29 | 29 |
| 15 | 35 | 8 | 23 | 40 | 27 |
| 16 | 35 | 8 | 21 | 40 | 25 |
| 17 | 40 | 10 | 38 | 46 | 25 |
| 18 | 85 | 2 | 4 | 13 | 13 |
| 19 | 56 | 0 | 0 | 19 | 13 |
| 20 | 81 | 0 | 17 | 8 | 13 |
| 21 | 67 | 4 | 2 | 33 | 13 |
| 22 | 79 | 2 | 0 | 40 | 19 |
| 23 | 90 | 8 | 0 | 25 | 13 |
| 24 | 38 | 2 | 4 | 10 | 52 |
| 25 | 50 | 4 | 0 | 50 | 23 |
| 26 | 48 | 0 | 0 | 29 | 31 |

The second greatest overall source of the preservice elementary teachers' answers was the category called "own observation." The answers were based on what the preservice teachers had observed from their own experiences. Often this category was combined with the information received from school to provide an answer for the interview.

Although school was the source given most often for questions 11, 12 and 20; TV was given as the second most noted source of information for these three answers. Question 11 read, "Will we ever run out of good clean water? Why or why not?" Question

12 read, "Where does the bathroom, sink, and toilet water go?" Question 20 read, "Define gravity."

The major source of preservice elementary school teachers' answers on the Sound Understanding Interview was school. This was true for answers which were rated as a sound understanding and for answers which were rated as a specific misunderstanding.

# CHAPTER V

# CONCLUSIONS, RECOMMENDATIONS, IMPLICATIONS, AND SUMMARY

The primary purpose of this study was to identify the water cycle concepts held by preservice elementary school teachers by using a paper and pencil multiple choice test and a clinical interview. A secondary goal was to determine the relationships between preservice elementary school teachers' water cycle knowledge and 1) the number of science courses taken, 2) the subject matter of the science courses taken, 3) the grade level preference for teaching, 4) the type of university attended, 5) the level of cognitive reasoning and 6) upper elementary children's water cycle knowledge. The following are conclusions, recommendations and implications for further study for each research question.

## Research Questions: Conclusions, Recommendations, Implications for Further Study

### Research Question 1

Is there a relationship between the number of science courses preservice elementary school teachers have taken and their water cycle knowledge?

Conclusion. The statistical data did not reveal that the number of science courses taken significantly affected water cycle knowledge. The WCAT mean score did increase in all three divisions (total number of college courses, total number of high school courses and total number of high school and college courses) from the least number of courses taken to the greatest number of courses taken. (Table I, II & III.) Even though the mean scores increased, the increase was not significant. This result would seem to say that having preservice elementary teachers take more science courses would not significantly increase their water cycle knowledge.

Recommendations. Institutions which prepare teachers should not simply add additional science courses to elementary education programs believing these additional courses will increase the knowledge of science concepts. The number of courses will not provide the solution.

Implications for further study. What other variables than those reported affect the WCAT mean score of preservice elementary school teachers? Since the WCAT is a paper and pencil test, does the variable of test taking skills affect the WCAT mean score? Table III indicated that some preservice teachers had not taken science courses in high school. Do preservice elementary school teachers take as many science courses as other college bound students? Most preservice elementary school teachers are females. Do high school counselors encourage female students to take as many science courses as possible during high school to build their science background?

Research Question 2

Is there a relationship between the subject matter of the science courses taken by preservice elementary school teachers and their water cycle knowledge ?

Conclusion. The subject of courses taken by preservice teachers did have a significant relationship to water cycle knowledge as tested on the paper and pencil WCAT multiple choice test for chemistry. The subjects of biology, earth and physical science and physics did not indicate a significant relationship to water cycle knowledge tested on the WCAT.

Recommendations. The lack of water cycle knowledge among preservice elementary teachers demonstrates the need for courses in high school and college which develop an indepth understanding of water cycle concepts. Chemistry course work appears to have an effect on water cycle knowledge, but only fifty-three percent of preservice teachers are likely to take this type of course based on fifty-two of the ninety-eight preservice teachers in this study who took a chemistry course (Table VI). From the data of this study, preservice elementary teachers should be encouraged to take chemistry in high school or college. Teacher education programs should include science courses which cover the chemistry content relating to water cycle concepts. If we assume inservice elementary school teachers have similar water cycle knowledge, there is a strong recommendation for chemistry concepts and in particular the kinetic molecular theory to be covered in inservice science workshops.

Implications for further study. Further research should be conducted to identify the chemistry course content which increases water cycle knowledge. This research indicated the kinetic molecular theory may be the chemistry content which is essential to water cycle knowledge. Research should be conducted to discern if science courses in high school and college cover the water cycle concepts. If they do not, at what grade levels are these concepts taught? Also, are water cycle concepts taught at the knowledge and comprehension level or at higher levels of cognitive thinking such as application and analysis?

## Research Question 3

Is there a relationship between the preservice elementary school teachers' grade level preference for teaching and their water cycle knowledge?

Conclusion. Though preservice elementary teachers who want to teach the primary grades (K-3) had a WCAT mean score of 15.76 and those who want to teach intermediate grades (4-6) had a WCAT mean score of 16.22, the grade level preference was not significantly related to knowledge of water cycle concepts on the paper and pencil WCAT multiple choice test. These results do not support the idea that most preservice elementary school teachers who want to teach the primary grades have significantly less knowledge of water cycle concepts than those who want to teach the upper grades.

Recommendations. Since water cycle concepts are taught in the elementary grades, preservice elementary school teachers will be teaching these concepts to children. Water cycle concepts need to be taught to preservice elementary teachers no matter what grade they prefer to teach. Individuals should not assume that those who teach or want to teach the primary grades want to do so because they possess less science knowledge and therefore feel better about teaching younger children.

Implications for further study. Research should be conducted to compare the water cycle knowledge of preservice elementary teachers, preservice secondary teachers, preservice secondary science teachers and all college majors. The testing should occur as these college students enter college and again after two college science courses have been taken. 1) Does their knowledge of water cycle conceptions improve after college courses are taken? 2) Is there a significant difference in water cycle knowledge between these groups of majors?

Research should be conducted to identify the major science concepts which are or should be taught in the elementary grades. Courses should be limited to these major concepts so there is sufficient time to study the concepts in depth.

Research Question 4.

Is there a difference between the water cycle knowledge of preservice elementary school teachers who attend a large public university compared to those who attend a small private university?

Conclusion. The type of university preservice elementary school teachers attended did not make a significant difference in water cycle knowledge. According to the WCAT mean score (Table X), the small private university student possessed significantly more knowledge, but on the SUI the number of sound understandings and the number of partial understandings were not significantly higher (Table IX). In addition, the small private university students had more "specific misunderstandings" than did the large public university students (Table VIII.).

Recommendations. Both large and small institutions preparing elementary school teachers have the same problem and need to take steps to correct this deficit in water cycle knowledge. Even though university students may be able to do well on multiple choice tests, they may not be able to explain the concepts tested and are likely to hold alternative conceptions. Curriculum revision should be implemented and evaluated in both large and small institutions.

Implications for further study. More research is needed to identify all the water cycle alternative conceptions that exist. This can be done by using clinical interviews which force people to describe their knowledge. Though this research will produce mainly descriptive data, alternative conceptions are identified which then can be used to create objective tests with the scientifically accurate answer and the alternative conceptions. These tests would be qualitative and provide for statistical data. Research could also look at the teacher education programs at large and small institutions to determine if such variables as number of science courses, subject matter within those science courses, and teaching strategies affect the water cycle knowledge of preservice elementary teachers. Large instituitons may tend toward having larger classes which in turn may affect the type of teaching strategies used.

Research Question 5

Is there a relationship between preservice elementary school teachers' water cycle knowledge and their level of cognitive reasoning?

Conclusion. The level of cognitive reasoning based on Burney's Logical Reasoning Test indicates a significant relationship with the mean score of the paper and pencil multiple choice test (WCAT). The more advanced the level of cognitive reasoning, the higher the score on the water cycle test. The lower the level of cognitive reasoning, the lower the score on the water cycle test. The level of cognitive reasoning did not have a significant relationship with the number of "specific misunderstandings" nor the "partial understandings" given in the interview. The fact that there is a relationship between levels of cognitive reasoning and multiple choice tests could be due to other variables such as testing skills, memorization of terminology or being provided with an appropriate answer; these do not occur in an interview.

Recommendation. Preservice teachers who think at the formal operational level possess alternative conceptions even though they score better on a paper and pencil test than those at the concrete operational level. Alternative conceptions are difficult to change. Giving more information usually does not disspell alternative conceptions. Since all levels of cognitive reasoning have alternative conceptions, all students need to experience the information so they will become aware of their alternative conceptions. Since preservice teachers, no matter what their level of cognitive reasoning, have alternative conceptions, college science professors will need to be knowledgeable about the existing alternative conceptions and plan experiences which will reveal those alternative conceptions to their students.

Implications for further study. Research should continue to expand the identification of water cycle alternative conceptions including methods to change these conceptions. However, neither of these will be helpful if scientifically accepted concepts are not taught to preservice elementary teachers. During the clinical interviews many of the preservice teachers defended their inability to explain the concepts to their staisfaction by proclaiming that they had not studied these concepts since grade school. Research should be conducted to verify whether the science training for elementary teachers includes the water cycle concepts.

Research Question 6

Question 6. Is there a difference between the water cycle knowledge of preservice elementary school teachers and upper elementary school children?

Conclusion. There was a significant difference between preservice elementary school teacher's knowledge of the water cycle and upper elementary children's knowledge. Preservice teachers demonstrated greater knowledge on the WCAT multiple choice test than the children. Preservice teachers also demonstrated greater knowledge by usually supplying more of the prerequisite concepts for the SUI questions than the children. Preservice teachers and elementary students differed on the number of "specific misunderstandings" for the questions in the interview. On some questions, preservice teachers' responses contained a greater number of "specific misunderstandings" and on other questions upper elementary children possessed more "specific misunderstandings." But, the significant discovery was how similar the "specific misunderstandings" were worded. Preservice teachers and upper elementary children stated the alternative conceptions using very similar wording.

Recommendations. Teachers will not be able to help children dispel their alternative conceptions if they as preservice teachers possess similar alternative conceptions. The science courses for elementary teachers must help preservice teachers identify their own alternative conceptions as well as acquaint them with typical misconceptions held by children. If preservice teachers do not become aware of alternative conceptions, they may actually foster the establishment of alternative conceptions in their students.

Implications for further study. Even though preservice teachers have more knowledge than upper elementary children about the water cycle, is the preservice teachers' water cycle knowledge of greater depth than the children's knowledge? Or, will some elementary students know as much as the classroom teacher? Further research should be conducted to determine: 1) at what grade levels we teach water cycle concepts and 2) does the level of thinking about water cycle information differ from grade to grade?

## Research Question 7

What degree of understanding do preservice elementary school teachers possess for water cycle concepts?

The conclusions, recommendations and implications for Research Question 7 will be handled differently than the previous questions. First, a general statement. This study revealed that preservice elementary school teachers do not have a sound understanding of water cycle concepts. More importantly, the Sound Understanding Interview revealed to the interviewees that they could not explain the phenomena. Many preservice teachers became very frustrated during the interview because they could not go beyond terminology. They were not upset with the questions, they were upset with themselves because they could not explain. For example, they could relate that clothes dry on a line because the sun and wind cause evaporation but they could not explain the process. These preservice teachers wanted the interviewer to interrupt the interview and provide them with appropriate instruction and explanations. These preservice teachers seemed to be experiencing what Piaget called disequilibrium. This was an opportune time for learning to take place. Using a similar type of interview may be an effective teaching strategy motivating students to want to understand and to be ready to learn. Getting students to apply their knowledge to everyday life by having them explain what has happened might be another way to assist them in discovering what they do not know.

Second, the discussion of Research Question 7 will be organized around the following water cycle concepts: 1) condensation, 2) evaporation, 3) kinetic molecular theory, 4) water treatment and 5) potable fresh water.

### Condensation

Conclusions. The concept of condensation was not understood by preservice elementary school teachers. None of the preservice teachers demonstrated a "sound understanding" on the condensation questions. Preservice teachers were more likely to give "no response" answers to condensation questions than to questions in any other category. McJunkin (1991) found similar results with upper elementary children. None of the preservice teachers were able to give all of the correct prerequisite concepts for condensation on the SUI. Preservice teachers knew that moisture is important for condensation to occur but were not aware of the importance that temperature plays in the process of condensation. Of those who realized that temperature is an important component, some believed the temperature must increase for rain to occur. This belief is an alternative conception.

Preservice teachers possessed a number of "specific misunderstandings" concerning condensation. Some of the alternative conceptions occurred as a result of misinterpreting what was taught in school and misinterpreting terminology of weather broadcasts. It would appear that even adults misinterpret what is verbally given. Without concrete examples, words take on a variety of meanings.Apparently, more than other concepts, condensation is difficult to understand. The author suggests this difficulty results from the learner having to deal with molecules of water which cannot be seen.

Recommendations.The high level of initial abstract learning may hamper the understanding of this concept. Evaporation should come first enabling the students to start with concrete experiences since evaporation starts with liquid water while condensation begins with the invisible water molecules. As an abstract concept, condensation may need to be taught when children are older. Many of the preservice teachers complained about not knowing the information because the last time they remembered having this information in school was when they were in elementary school. When this information is taught, it should be made as concrete as possible. Verbal explanations are too abstract. Secondly, condensation must be applied to every day lives. How does the grass get wet in the morning? How does moisture form or not form on a can of soda? How does moisture or frost form on windows? This requires that students think about science concepts at higher levels of thinking (application, analysis, etc.) rather than the memorization of terms and definitions. More time needs to be given to essential concepts so that students have the time it takes to study a concept in depth. Without time to construct and internalize a concept, each year may be spent rememorizing the same information rather than learning more.

Implications. Classroom teachers are very dependent on science textbooks. Studies should be initiated to determine what prerequisite concepts make up the conceptual schema for condensation. We need to learn at what age these concepts should be taught and what textbook series have an appropriate scope and sequence. If there are no appropriate texts, new textbooks need to be written. Secondly, studies should continue to identify the specific misunderstandings that preservice elementary school teachers and children possess concerning condensation following implementation of appropriate instruction.

Evaporation

Conclusions. Preservice elementary school teachers scored the highest for the concept of evaporation. SUI questions on evaporation had some of the highest percentage of "sound understandings" responses and the same was true about evaporation questions on the WCAT. Inspite of the preservice teachers' knowledge of evaporation, there were a number of "specific misunderstandings." Even those preservice teachers who could explain the process of evaporation for a particular question because they had experienced the concept in a laboratory experience in school, were not able to transfer that process to experiences in daily living. For example, they could explain how molecules evaporate from water boiling in a beaker of water but did not transfer their knowledge of molecules to explain how water evaporates from clothers drying on a clothes line. Most of their specific misunderstandings were due to their inaccurate understanding of the kinetic molecular theory such as what happens to the molecules during evaporation and what part heat plays in the process.

Recommendations. Preservice teachers seem to have more knowledge about evaporation than condensation, but there are still problems. Preservice teachers need to become aware of the specific misunderstandings they possess as well as those that their students may possess. Science courses for preservice elementary school teachers and teachers' manuals should include correct background describing corrections for the specific misunderstandings that exist. Even though some preservice teachers could explain the molecular movement in evaporation, rarely were they able to apply this information to every day experiences where evaporation takes place. Science courses for preservice elementary school teachers should provide experiences where concepts are given practical application. Teachers' manuals should include these applications.

Implications. Additional studies need to be conducted in regard to the alternative conceptions which preservice elementary school teachers possess concerning evaporation. What do preservice teachers believe about: how molecules get their energy, what happens to the physical make-up of the molecules during evaporation, whether steam is a part of evaporation or not, and what the wind does to evaporating molecules.

Kinetic molecular theory

Conclusions. Preservice teachers do not have a "sound understanding" of this concept. The kinetic molecular theory questions for the WCAT were questions about energy and the states of matter. These were typically knowledge level questions. On the SUI, preservice teachers did not do as well. Seldom did a participant mention the kinetic molecular theory in answering. When participants mentioned molecular movement in their answers, they were then encouraged to name the type of energy, few of these gave kinetic energy. Only twenty-seven percent of preservice teachers included the word "molecules" in answers that required this information. Those who included molecules in their answers revealed a number of "specific misunderstandings" about the characteristics of molecules. Preservice teachers might use the appropriate terminology but additional probing revealed their concepts of the terminology were inaccurate. A common example was "molecules expand." Some preservice teachers believed the molecules increased in size not that they moved farther apart.

Recommendations. Preservice elementary school teachers do not automatically think of this theory when they are explaining evaporation and condensation. Science courses for preservice elementary teachers need to include an indepth study of the kinetic molecular theory and the characteristics of molecules. Preservice teachers need to identify their alternative conceptions regarding water cycle concepts and be aware of the alternative conceptions of elementary childrem.

Implications. Additional studies should be conducted to discern if alternative conceptions exist among other preservice elementary school teachers and to discover what preservice elementary teachers know about the kinetic molecular theory. Studies should be conducted to check preservice elementary teachers' understanding of terminology related to molecules. This study found that "molecules expand/molecules contract" meant different things to different preservice elementary teachers. Are there other words that carry meanings that would lead to alternative conceptions?

Water treatment

Conclusions. Preservice elementary school teachers are not knowledgeable about water treatment. They do not know what happens to sewage. Even though sixty-nine percent knew sewage goes to a purification plant only forty-four percent named this as a way to make water cleaner (Question 13). Of the above forty-four percent, only one fourth could adequately explain what took place in a purification plant. Only thirty-three percent of preservice elementary teachers knew that sewage may go into a septic tank and only a third of these (11%) could explain what happens in a septic tank. Very few preservice teachers (27%) know that evaporation is a natural means of purifying water. This is another indication of their lack of understanding.

Recommendations. Water use and treatment must become part of the public high school curriculum and of the teacher preparation institutions' curriculum. For example, preservice elementary school teachers might be taken on a field trip to a purification plant after they have studied water treatment. Not only would this develop the preservice teachers' knowledge but it would model an appropriate way to teach their students.

Implications. Studies should be initiated to determine whether field trips to water treatment plants and other strategies are effective teaching strategies for elementary students or is this material best left to be studied in high school.

Potable fresh water

Conclusions. Preservice elementary school teachers are not knowledgeable concerning fresh water, even though two (Questions 15 & 24) of the four questions which had the highest percentage of sound understanding answers were about fresh water. This is misleading. Ninety-two percent of the preservice teachers answered Question 15 (Can you drink from any well?) correctly. This question only required a yes or a no answer. No explanation was required. The explanation was given in Question 16 (Why or why not?). None of the answers were scored as sound understanding while forty-six percent were scored as specific misunderstandings (Table XXIV). Only twenty-five percent of the answers for Question 24 (Define ground water.) were scored as sound understanding (Table XXIV). These preservice teachers were not familiar with the term, groundwater, but guessed at the meaning by defining the ground and water. Preservice teachers do not understand what forms a well. Only twenty-three percent knew that a well must be deeper than the water table. Some believe that wells can only exist where there is an underground lake or river. In addition, preservice teachers are not well informed about water pollutants. They more often referred to minerals as pollutants rather than to heavy metals, detergents, acid rain or petroleum.

Recommendations. The science courses for preservice elementary school teachers should include studies about fresh water. Concepts such as ground water, wells, water table, and groundwater pollutants should be included. Science teachers need to be aware of the alternative conceptions preservice elementary school teachers possess.

Implications. Additional studies should be conducted to discover how preservice teachers perceive ground water and aquifers. Questions need to be answered such as: Can preservice teachers explain what is meant by the water table? Also, alternative conceptions need further study. Do preservice teachers believe minerals pollute the ground water? What does the word "pollute" mean to them? What is being said about sulfur that makes preservice teachers believe that sulfur is harmful? Do preservice teachers believe the deeper the water is in the ground, the purer it is? Do preservice teachers believe that the faster water flows, the purer it is?

## Research Question 8

Question 8. What is the preservice elementary school teachers' source of water cycle information?

Conclusion. School is the preservice elementary school teachers' major source of water cycle information. Preservice elementary teachers also frequently identified their "own observation" as a source of water cycle information. Television, people (other than teachers), reading materials (other than textbooks), and radio were not identified as major sources of water cycle information (Table XXV).

Recommendations. Teachers and textbook authors must be made aware of their importance as primary sources for the water cycle knowledge of preservice elementary school teachers. Teachers and textbook authors should ask these questions. Have we presented an accurate picture? Could this terminology be misleading? How will the student perceive this information? Evaluation must become more sensitive to the existence of word-rich concept-poor students at all levels.

Implications for further study. Future studies should distinguish between the source for an appropriate prerequisite and the source for a specific misunderstanding. Identifying the source of an answer does not necessarily mean it is also the source of the specific misunderstanding. When a specific misunderstanding is given, the source should be identified.

Future study should be done to determine how weather broadcast terminology affects preservice elementary teachers' understanding of water cycle concepts. In particular, preservice elementary teachers need to understand what happens when a cold and warm front meet and how that collison causes precipitation.

## Summary

Preservice elementary school teachers do not know the present scientifically accepted explanations of water cycle concepts. On the twenty-three item Water Cycle Assessment Test, the mean score for the entire sample of ninety-eight was 15.84. This indicates that an average of sixty-nine percent of the questions were answered correctly. In the twenty-six item Sound Understanding Interview (Table XV), preservice teachers did not demonstrate sound understanding of the water cycle concepts. The highest percentage of sound understanding was ninety-two percent for Question 15 ("Can you drink from any well?"). This only required a yes or no response. Question 16 ("Why or why not?") required the explanation and only two percent gave an answer of sound understanding. All other questions had very low percentages of sound understanding with twenty-nine percent being the highest.

Preservice elementary teachers did demonstrate significantly more knowledge of water cycle concepts than upper elementary children for the Water Cycle Assessment Test. Preservice teachers' mean score was 15.84 and upper elementary children's mean score was 10.15. Preservice elementary teachers may know more content but this does not reveal whether they have greater understanding of the content than do elementary children. When these preservice teachers become classroom teachers, their knowledge may be at the same level as their students.

Preservice elementary school teachers do possess alternative conceptions which are similar to those expressed by upper elementary children in the Water Cycle Assessment Test and in the Sound Understanding Interview. As children, preservice teachers have developed alternative conceptions by applying everyday explanations to scientific terminology. In normal conversation, the word "expand" would mean to increase in size. When molecules expand, they do not increase in size; they move farther apart. When the word expand was used with molecules some preservice teachers interpreted "expand" to mean that the molecules increased in size. Preservice teachers are as likely to explain the water cycle concepts out of their "own observation" when their school knowledge is insufficient as do elementary children. Alternative conceptions were held by preservice teachers whether they tested as formal or concrete operational thinkers. Concrete thinkers had a mean score of 11.5 for their number of specific misunderstandings and formal thinkers had a mean score of 11.48 for their number of specific misunderstandings. Formal reasoners did significantly better on the WCAT but actually revealed more specific misunderstandings on the SUI. Formal reasoning helps when thinking about the words on a test but may have little effect on changing the conceptusl framework.

Two variables had a significant relationship to preservice elementary teachers' water cycle knowledge as evaluated by the Water Cycle Assessment Test. One was chemistry course work and the other was the level of cognitive reasoning. Chemistry is important because the kinetic molecular theory is an important concept in this subject. The kinetic molecular theory may be a very essential prerequisite concept or "criterial attribute" for understanding water cycle concepts. Logical reasoning has been identified by a number of studies as essential to learning formal concepts (Hewson, 1986; Shepherd & Renner, 1982; & Tobin & Capie, 1981), but formal reasoners did not do significantly better on the Sound Understanding Interview. The other high school and college subjects, the number of science courses completed, the grade level preference for teaching and the type of university attended did not have a significant relationship to the level of water cycle knowledge.

The intent of this research was to add to the growing body of information about water cycle concepts in four areas:

1) Water cycle concepts held by preservice elementary school teachers.

2) The water cycle alternative conceptions of preservice elementary school teachers.

3) The similarities and differences of water cycle concepts between preservice elementary school teachers and upper elementary children.

4) Variables which do and do not affect water cycle knowledge such as preservice elementary teachers' level of cognitive reasoning, the number and types of science courses taken by preservice elementary teachers and the type of university the preservice elementary teacher is attending.

The statistical and descriptive data of this study has added important information to the above four areas and disclosed other relevant questions needing further research.

If the above variables are not significant aspects of developing a sound understanding of water cycle concepts perhaps we are looking for a quick fix for developing understanding when there is not one available. Understanding includes experiencing the concept in many different ways, trying to use it to solve every day problems, and pulling the concept apart to look at its components. Maybe that is why Piaget believes we should supply the materials and experience that allow students to construct their own conceptual framework rather than telling students the information.

The study of the water cycle disclosed another cycle. Children who acquired and maintained alternative conceptions throughout their education become teachers whose alternative conceptions are similar to their students. Therefore, the alternative conceptions are not revealed and the cycle begins again. This cycle must be broken in order for all citizens in our democracy to acquire scientific literacy so that individuals may make appropriate decisions in our technological society.

REFERENCES

Abimbola, I. O. (1988). The problem of terminology in the study of student conceptions in science. Science Education, 72(2), 175-184.

Albert, E. (1978). Development of the concept of heat in children. Science Education, 62(3), 389-399.

Alvarez, M. C. &. R., Victoria (1987). Using Vee Diagrams to Clarify Third Grade Students' Misconceptions During a Science Experiment. In J. D. Novak (Ed.), Misconceptions and Educational Strategies in Science and Mathematics, I (pp. 6-14). Ithaca, NY: Cornell University.

Amir, R. ;. Frankl, P. & Tamir (1987). Justification of Answers to Multiple Choice Items as a Means of Identifying Misconceptions. In J. D. Novak (Ed.), Misconceptions and Educational Strategies in Science and Mathematics, I (pp. 15-25). Ithaca, NY: Cornell University.

Arends, R. I. (1988). Learning to Teach. New York: Random House.

Ault, C. R. (1984). Intelligently wrong, some comments on children's misconceptions. Science and Children, 20(6), 21-24.

Audette, R. M. L. (1987). Acid rain is killing more than lakes and trees. Environmental Action, 18(6), 10-13.

Ausubel, D. P. ;. Novak., J D.; & Hanesian, H. (1978). Educational Phychology A Cognitive View (2nd ed.). New York: Holt, Rinehart & Winston.

Bar, V. (1987). The Effect of the Testing Format on the Distribution of the Results. In J. D. Novak (Ed.), Misconceptions and Educational Strategies in Science and Mathematics, I (pp. 26-31). Ithaca, NY: Cornell University.

Beveridge, M. (1985). The development of young children's understanding of the process of evaporation. British Journal of Education Psychology, 55, 84-90.

Bourne, L. E. J. (1966). Human Conceptual Behavior. Boston: Allyn & Bacon.

Boyd, C. (1963). A study of unfounded beliefs. Science Education, 50(4), 396-398.

Brody, M. J. (1987). A Programmatic Approach to Teaching and Learning About Student Understanding of Science and Natural Resource Concepts Related to Environmental Issues. In J. D. Novak (Ed.), Misconceptions and Educational Strategies in Science and Mathematics, 1 (pp. 67-81). Ithaca, NY: Cornell University.

Bruner, J. S. (1960). The process of education. Cambridge: Harvard University Press.

Burney, G. M. (1974). The construction and validation of an objective formal reasoning instrument. Unpublished doctural dissertation, University of Northern Colorado, Greeley.

Cantu, L. L., & Herron, J. D (1978). Concrete and formal Piagetian stages and science concept attainment. Journal of Research in Science Teaching, 15(2), 135-143.

Carey, S. (1986). Cognitive science and science education. American Psychologist, 41(10), 1123-1130.

Champagne, A. B. ;. Klopfer, L. E.; & Gunstone, R. F. (1982). Cognitive research and the design of science instruction. Educational Psychologist, 17(1), 31-53.

Champagne, A. B. &. Klopfer, L. E. (1983). Naive Knowledge and Science Learning. New York, NY: American Association of Physics Teachers.

Chiappetta, E. L. (1976). A review of Piagetian studies relevant to science instruction at the secondary and college level. Science Education, 60(2), 253-261.

Clement, J. (1982). Student's preconceptions in introductory mechanics. American Journal of Physics, 50(1), 66-71.

Cohen, M. R. (1971). Developing a teacher's awareness of children. Science and Children, 24-27.

Confrey, J. (1987). 'Misconceptions' Across Subject Matters: Science, Mathematics and Programming. In J. D. Novak (Ed.), Misconceptions and Educational Strategies in Science and Mathematics, I (pp. 81-106). Ithaca, NY: Cornell University.

Cosgrove, M. &. Osborne, R. (1981). Physical Change. Learning in Science Project. Hamilton, New Zealand: Waikato University.

Crawley, F. E., & Arditzoglou, S. Y. (1988, December 2-3). Life and physical science misconceptions of preservice elementary teachers. Paper presented at the School Science and Mathematics Association, Austin, TX.

Culver, A. &. Aydette , R. M. (1985). Danger's in the well. Environmental Action, 16(6), 15-19.

Doran, R. (1972). Misconceptions of selected science concepts held by elementary school students. Journal of Research in Science Teaching, 9(2), 127-137.

Duit, R. (1987). Research on Students' Alternative Frameworks, Consequences for Science Teaching. Misconceptions and Educational Strategies in Science and Mathematics, 1 (pp. 151-162). Ithaca, NY: Cornell University.

Dykstra, D. J. (1987). Education in elementary school: some observations. Journal of Research in Science Teaching, 24(2), 179-182.

Eaton, J. F. ;. Anderson, C. W.; & Smith, E. L. (1983). When students don't know they don't know. Science and Children, 20(7), 6-9.

Eaton, J. F. ;. Anderson, C. W.; & Smith, E. L. (1984). Students misconceptions interfere with science learning: case studies of fifth-grade students. The Elementary School Journal, 84(5), 365-379.

Ecklund, D. (1987). Telephone interview with president of the Association. N.Y., N.Y.: Association of American Publishers

Engelmann, S. (1969). Conceptual Learning. Belmont, CA: Fearon Publishers.

Erickson, G. L. (1979). Children's conception of heat and temperature. Science Education, 63(2), 221-230.

Feldsine, J. E. (1987). Distinguishing Students Misconceptions from Alternative Conceptual Frameworks Through the Construction of Concept Maps. In J. D. Novak (Ed.), Misconceptions and Educational Strategies in Science and Mathematics, I (pp. 177-181). Ithaca, NY: Cornell University.

Finley, F. N. (1984). Using propositions from clinical interviews as variables to compare student knowledge. Journal of Research in Science Teaching, 21(8), 809-818.

Finley, F. N. (1985). Variations in prior knowledge. Science Education, 69(5), 697-705.

Fisher, K. M. ;. &. Lipson, J. I. (1986). Twenty questions about student errors. Journal of Research in Science Teaching, 23(9), 783-803.

Fisher, K. M. ;. Lipson, J.I.; Hildebrand, A.C.; Miguel, L.; Schoenberg, N.; & Porter, N. (1986). Student misconception and teacher assumptions in college biology. Journal of College Science Teaching, 15(4), 276-280.

Franz, J. R. ;. &. Enochs, L. G. (1982). Elementary school science: state certification requirements in science and their implications. Science Education, 66(2), 287-292.

Gagne, R. M. (1977). The Condition of Learning (3rd ed.). New York: Holt, Rinehart & Winston.

Garnett, P. J. ;. &. Tobin, K. (1984). Reasoning patterns of preservice elementary and middle school science teachers. Science Education, 68(5), 621-631.

Ginns, I. S. ;. &. Foster, W. J. (1983). Preservice elementary teacher attitudes to science and science teaching. Science Education, 67(2), 277-282.

Good, C. V. (1973). Dictionary of Education. (3rd. ed.). NY:McGraw Hill.

Gunstone, R. F. (1982). Cognitive research and the design of science instruction. Educational Psychologist, 17(1), 31-53.

Harvey, P. (1988, June17). Is drought taking us on a road to starvation? Los Angeles Times.

Hashweh, M. (1988). Descriptive studies of students' conceptions in science. Journal of Research in Science Teaching, 25(2), 121-134.

Helm, H. &. Novak, J. D. (1983). Proceedings of the International Seminar. I (p. 984). Cornell University, Ithaca, NY, USA:

Hewson, M. G. A. (1986). The acquisition of scientific knowledge: analysis and representation of student conceptions concerning density. Science Education, 70(2), 159-170.

Hill, J. W. (1984). Chemistry for Changing Times (4th ed. ed.). Minneapolis: Burgess.

Hollon, R. &. Anderson, C. (1986). Heat and Temperature: A Teaching Model. Michigan State University.

Joyce, B. &. Weil , M. (1980). Models of Teaching (2nd ed.). Englewood Cliffs, NJ: Prentice Hall, Inc.

Kagan, D. M. ;. Albertson, L. M.; Dick, J.; & Sadler, E J. (1986). Cognitive level and self-evaluation of pre-service teachers. The Teacher Educator, 22(1), 18-27.

Klausmeier, H. J. &. Harris, C. W. (1966). Analysis of Concept Learning. New York: Academic Press.

Klausmeier, H. J. (1980). Learning and Teaching Concepts. New York: Academic Press.

Kuethe, J. L. (1963). Science concepts: a study of "sophisticated" errors. Science Education, 47(4), 361-364.

Lawrenz, F. (1986). Misconceptions of physical science concepts among elementary school teachers. School Science and Mathematics, 86(8), 654-660.

Lawson, A. E. ;. Nordland, F. H.; & DeVito, A. (1975). Relationship of formal reasoning to achievement, aptitudes, and attitudes in preservice teachers. Journal of Research in Science Teaching, 12(4), 423-431.

Lawson, A. E. &. Blake, A. J.D. (1976). Concrete and formal thinking abilities in high school biology students as measured by three separate instruments. Journal of Research in Science Teaching, 13, 227-235.

Lawson, A. E. ;. &. Snitgen, D. A. (1982). Teaching formal reasoning in a college biology course for preservice teachers. Journal of Research in Science Teaching, 19(3), 233-248.

Lawson, A. E. (1983). Predicting science achievement: the role of developmental level, disembedding ability, mental capacity, prior knowledge, and beliefs. Journal of Research in Science Teaching, 20(2), 117-129.

Lawson, A. E. (1985). A review of research on formal reasoning and science teaching. Journal of Research in Science Teaching, 22(7), 569-617.

Lawson, A. E. (1988). The acquisition of biological knowledge during childhood: cognitive conflict or tabula rasa? Journal of Research in Science Teaching, 23(3), 185-199.

Lawson, A. E. ;. &. Thompson, L. D. (1988). Formal reasoning ability and misconceptions concerning genetics and natural selection. Journal of Research in Science Teaching, 25(9), 733-746.

Licht, J. &. Johnson, J. (1985). Without a paddle. Environmental Action, 17(2), 10-13.

Linn, M. C. (1987). Establishing a research base for science education: challenges, trends, and recommendations. Journal of Research in Science Teaching, 24(3), 191-216.

Manning, P. E.; Esler, W. K.; & Baird, J. R. (1982). How much elementary science is really being taught? Science and Children, 19(8), 40-41.

Marek, E. (1986). Understandings and misunderstanding of biology concepts. The American Biology Teacher, 48(1), 37-40.

Martin, E. R. (1983). Who are our teacher education students. Journal of Teacher Education, 24(1), 51-53.

Mattingly, R. L. (1987). The dynamics of flowing water. The Science Teacher, 54, 23-27.

McJunkin, M. (1991). Elementary children's concepts of the water cycle. Unpublished doctoral dissertation, Oklahoma State University, Stillwater, OK.

McNeil, J. D. ;. &. Keislar, E. R. (1962). An experiment in validating objectives for the curriculum in elementary school science. Science Education, 46, 152-156.

Meyer, L. A. ;. Crummey., L.; & Greer, E. A. (1988). Elementrary science textbooks: their contents, text characteristics, and comprehensibility. Journal of Research in Science Teaching, 25(6), 435-463.

Mintzes, J. J. (1984). Naive theories in Biology: children's concepts of the human body. School Science and Mathematics, 84(7), 548-555.

Moore, R. W. (1973). The development, field test, and validation of scales to assess teachers' attitudes toward teaching elementary school science. Science Education, 57(3), 271-278.

Morton, S. D. (1976). Water Pollution - Causes and Cures. Madison: Mimir Publishers, Inc.

Mulopo, M. M. &. Fowler., H. S. (1987). Effects of traditional and discovery instructional approaches on learning outcomes for learners on different intellectual development: a study of chemistry students in Zambia. Journal of Research in Science Teaching, 24(3), 217-227.

Neiburger, M. ; Edinger, J.; & Bonner, W. D. (1973). Understanding our Atmospheric Environment. San Francisco: W.H. Freeman & Co.

Novak, J. D. (1987). Misconceptions and Educational Strategies in Science and Mathematics. Proceedings of the International Seminar. Misconceptions and Educational Strategies in Science and Mathematics, I & II (pp. 1064). Ithaca, NY: Cornell University.

Novick, S. &. Novak., J. (1978). Junior high school pupils understanding of the particulate nature of matter: an interview study. Science Education, 62(3), 273-381.

Novick, S. &. Novak, J. (1981). Pupils understanding of the particulate nature of matter: a cross-age study. Science Education, 65(2), 187-196.

Nussbaum, J. &. Novak, J. D. (1976). An assessment of children's concepts of the earth utilizing structured interviews. Science Education, 60(4), 535-550.

Nussbaum, J. (1979). Children's conceptions of the earth as a cosmic body: a cross-age study. Science Education, 63(1), 83-93.

Nussbaum, J. &. Novick, S. (1982). Alternative frameworks, conceptual conflict and accomodation: toward a principled teaching strategy. Instructional Science, 11(3), 183-200.

Oickle. E. M. Ed. (1972). Unified science approach K-12, proficiency levels 7-12. Anne Arundel Conty Board of Education, Annapolis, MD. ED 079 055

Olstad, R. G. & Haury, D. L. (1984). A summary of research in science education - 1982. Science Education. 68(3), 207-209.

Osborne, R. J. &. Cosgrove, M. M. (1983). Children's conceptions of the changes of state of water. Journal of Research in Science Education, 20(9), 825-838.

Osborne, R. J. &. Wittrock, M.C. (1983). Learning science: a generative process. Science Education, 67(4), 489-508.

Padilla, M. J. (1981). The Relationship Among Formal Operational Abilities, Selected Achievement Variables and Student Teaching Success. NY, NY: ED 201 491.

Perez, G. D. &. A, Carrascosa J. (1987). What To Do for Science Misconceptions. In J. D. Novak (Ed.), Misconceptions and Educational Strategies in Science and Mathematics, II (pp. 149-157). Ithaca, NY: Cornell University.

Peterson, S. (1985). An imperiled majesty. Environmental Action, 16(5), 16-20.

Piaget, J. (1960). The Child's Conception of the World (Joan & Andrew Tomlinson, Trans.). Peterson, N.J.: Littlefield, Adams & Co.

Pines, A. L. &. West, L.H.T. (1970). Conceptual understanding and science learning: an interpretation of research within a sources-of-knowledge framework. Science Education, 70(5), 583-604.

Posner, G. J. ;. Strike, K.A.; Hewson, P.W.; & Gertzog, W.A. (1982). Accomodation of a scientific conception: toward a theory of a conceptual change. Science Education, 66(2), 211-227.

Prather, J. P. (1985, April 15-18). Philosophical examination of the problem of the unlearning of incorrect science concepts Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, French Lick Springs, IN.

Renner, J. W. ;. Abraham, M.R.; Grzybowski, E.B.; & Marek, E.A. (1990). Understandings and misunderstandings of eighth graders of four physics concepts found in textbooks. Journal of Research in Science Teaching, 27(1), 35-54.

Richardson, V. (1987). Educator's Handbook. White Plains, NY: Longman.

Ridgeway, D. (1988). Misconceptions and the Qualitative Method. The Science Teacher, 55(6), 68-71.

Roadrangka, V. &. Yeany, R.H. (1985). A study of the relationship among type and quality of implementation of science teaching strategy, student teaching formal reasoning ability, and student engagement. Journal of Research in Science Teaching, 22(8), 743-760.

Roberts, R. S. (1980). Cuncurrent validity in tests of Piagetian developmental levels. Journal of Research in Science Teaching, 17(4), 343-350.

Rogan, J. M. (1988). Development of a conceptual framework of heat. Sciece Education, 72(1), 103-113.

Santmire, T. E. (1985). The Ninth Mental Measurements Yearbook. Lincoln, Nebraska: University of Nebraska Press.

Saunders, W. L. &. Shepardson, D. (1987). A comparison of concrete and formal science instruction upon science achievement and reasoning ability of sixth grade students. Journal of Research in Science Teaching, 24(1), 39-51.

Shayer, M. &. Wylam, H. (1981). The development of the concepts of heat and temperature in 10 - 13 year olds. Journal of Research in Science Teaching, 18(5), 419-434.

Sheaffer, J. R. (1984). Circular versus linear water systems: going back to nature's way. Environment, 26(8), 10-13.

Shepherd, D. L. ;. &. Renner, J.W. (1982). Student understandings and misunderstandings of states of matter and density changes. School Science and Mathematics, 82(8), 650-665.

Shrigley, R. L. (1974). The correlation of science attitude and science knowledge of preservice elementary teachers. Science Education, 58(2), 143-151.

Silverman, F. L. &. Creswell, J. L. (1982). Preservice teachers: a profile of cognitive development. Texas Tech Journal of Education, 9(3), 175-185.

Smith, D. C. (1984, Oct 25). Cognitive processes and students' misconceptions in science. Paper presented at the Annual Meeting of the Northeastern Education Research Association, Ellenville, NY.

Stepans, J. & Kuehn, C. (1985). Children's conceptions of weather. Science and Children, 23(1), 44-47.

Straham, D. (1986, Mar). A developmental analysis of formal reasoning in the middle schools. Paper presented at the Eastern Educational Research Association, Miami Beach, FL.

Sunal, D. W. (1982). Affective predictors of preservice science teaching behavior. Journal of Research in Science Education, 19(2), 167-175.

Szabo, S. E. (1986). Teaching Abstract Concepts in Sociology. (ED 275 602)

Tobin, K. &. Capie, W. (1981). The development and validation of a group test of logical thinking. Educational and Psychological Measurement, 41, 413-423.

Trembath, R. J., & Barufaldi, J. P. (1981, April 5-8). The frequencies and origins of scientific misconceptions. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, 54th. Grossingers in the Catskills, Ellenville, NY.

Truax, R. H. (1986). Lust in America. Environmental Action, 18(2), 23-26.

Ucko, D. A. (1982). Basics for Chemistry. New York: Academic Press.

Vosniadou, S. (1988, April 5-9). Knowledge restructuring and science instruction. Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA.

Wandersee, J. H. (1985). Can the history of science help science educators anticipate students' misconceptions. Journal of Research in Science Teaching, 23(7), 581-597.

Watts, D. M. &. Gilbert, J.K. (1983). Enigmas in school science: students' conceptions for scientifically associated words. Research in Science and Technological Education, 1(2), 161-171.

Welch, W. W. (1979). Twenty years of science curriculum development: a look backward. In D. Berliner (Ed.), Review of research in education (Vol. 2) Washington, D.C.: American Educational Research Association.

Westerback, M. E. (1982). Studies on attitude toward teaching science and anxiety about teaching science in preservice elementary teachers. Journal of Research in Science Teaching, 19(7), 603-616.

Wilson, D. A. (1988). An assessment of water knowledge among 4th, 6th, and 8th grade students. Masters, Oklahoma State University, Stillwater, Oklahoma.

Yager, R. E., & Lunetta, Vincent N. (1984). New foci for science teacher education. Journal of Teacher Education, 35(6), 37-42.

Young, D. B., & Tamir, P. (1977). Finding out what students know. The Science Teacher, 44(6), 27-28.

Zeitler, W. R. (1984). Science backgrounds, conceptions of purpose, and concerns of preservice teachers about teaching children science. Science Education, 68(4), 505-520.

APPENDIXES

APPENDIX A

MCJUNKIN'S INTERVIEW QUESTIONS

McJunkin's Interview Questions

(The following is the list of questions which were used in the clinical interviews of the elementary children. These will be revised and added to for the preservice teachers' interview.)

1. (Demonstration)I am going to light this candle under this pan which has water in it, will anything happen to the water?
2. (Demonstration)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. What causes clothes to dry?
    - a. Where do you think the water goes?
    - b. Can you see the water after it leaves the clothes?
    - c. Can we still call it water?
        1. Is it the same water that was in the clothes?
        2. What is the difference?
    - d. What if the clothes had no air moving around them? no heat?
4. Ask students where rain comes from and ask them to draw it on a blank sheet of paper.
    - a. When the rain goes to the earth, where does it go?
    - b. Where does lake and stream water come from?
    - c. How does the water get in the cloud?
    - d. What makes it rain?
5. Where do clouds come from?
    - a. How does it happen?
    - b. What do you think clouds are made of?
    - c. How do they get up in the sky?
    - d. Does it rain everytime clouds are in the sky?
        1. Yes - Can it be cloudy with no rain?
        2. No - Is there water up there?
        3. Yes - If so, why doesn't it fall down?
        4. No - If there weren't any clouds could it rain just the same?
        5. What makes rain fall?
6. Is more of the earth's surface covered by water or land? Why do you think so?
    - a. Where would you go to find the greatest amount of water? Why do you think
    - b. Is there so much good clean water that we could never run out? What are your reasons for thinking this?
    - c. Where does good clean water come from?
    - d. Can you drink from any pond, lake, stream, or river? Why not?
    - e. How would you get it clean?
    - f. Why, isn't the water that comes from our facets dirty?
7. Where does our dirty water go that comes from our bathtubs, sinks, and toilets?
8. Where does dirty water go that comes from our factories?
9. (Demonstration) From where has the water on the outside of the jar come?
10. Explain what these words mean to you as you think about them in your mind:
    - a. evaporation
    - b. condensation
    - c. gravity
    - d. melting
    - e. boiling
    - f. freezing
    - g. ground water
    - h. steam
    - i. water vapor

# APPENDIX B

# VALIDATED ANSWERS

# VALIDATED ANSWERS FOR SUI

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
Some fast moving molecules on the surface escape
Liquid water becomes water vapor

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 into the air.

Heat energy is added
Heat energy becomes 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
Air around paper towel is replaced with air that contains fewer water molecules, thus allowing more water molecules to escape from the spot

3. What causes the clothes to dry? (Will be shown a picture of clothes drying on a clothes line.)

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 heat
Heat becomes 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

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

No, water vapor is invisible.

5. Can we still call it water?

Yes, but it is in a gaseous form.

6. 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 because they are further apart. Heat is then taken from the water vapor as it rises. 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 come closer and closer to each other until liquid is formed. The joining together of water molecules occurs more readily if condensation nuclei (dust, smoke particles, etc.) are present for these molecules to attach to. The process of condensation has occurred. These clusters of water molecules or particles are seen as clouds.

Heat from the sun becomes 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 to 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

7. How do clouds get up 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. This wind movement takes water vapor up into the sky where it is cooled and forms clouds.

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

8. What makes it rain? (Does it rain everytime clouds are in the sky?)

Precipitation depends on the amount of water vapor, temperature, and particles in the air. The air must be saturated with water vapor. In order for that water vapor to condense, the temperature of the air must fall below what is called the dew point. The presence of particles in the air 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 become large enough to overcome updraft of air
Gravity will pull clusters to the earth

9. 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 air
Molecules collide with sides of 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

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

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

11. 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% of the world's population has assess to sufficient clean 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

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

To a septic tank
    Sedimentation

Filtered through rocks and soil
Or to a water purification plant.
Or released unclean into lakes or rivers

13. How would you get it clean?

There are a number of means to help purify water. Sewage and industrial wastewater must undergo treatment. During treatment filters and sedimentation help remove suspended solids. Next certain bacteria are useful in decomposing waste. Finally, chemicals are used to remove specific pollutants. Another means to help purify water is boiling. Boiling destroys some harmful bacteria. Another means is distillation which also takes place in the natural form of evaporation. Another natural means of helping to purify water is as ground water flows through the rocks and soil, some impurities are removed.

Water purification plant
Filters & sedimentation
Bacteria which eats waste
Chemicals
Boiling
Distillation/Evaporation
Flowing through soil and rocks

14. 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 restricts the passage of 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 water table

15. Can you drink from any well?

No

16. Why or why not?

Not if pollutants are present. Pollutants may include:
Heavy metals: mercury, lead, cadmium, etc.
Pesticides & herbicides
Oil
Synthetic detergents (phosphates)
Bacteria or virus (feces & urine of humans or animals)
Acid rain

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

No, not if pollutants are present. Pollutants may include:
Heavy metals

Pesticides & herbicides
Oil
Synthetic detergents
Bacteria or virus
Acid rain

18. Define evaporation.

Liquid changes into a vapor when heat is absorbed. 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 away from the rest of the liquid molecules thus changing from liquid to vapor.

Heat increases kinetic molecular energy
Water molecules move with different kinetic energies
Molecules move fast when heat is absorbed
Molecules move farther apart, lessening molecular attraction
Some surface molecules escape from liquid
Liquid water becomes water vapor
Water vapor is invisible

19. 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 more strongly 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
Water vapor becomes liquid water

20. 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
Particles of matter are pulled toward each other
Matter on or near the earth is pulled toward the center of the Earth

21. Define melting.

Enough heat energy has been added to allow the molecules of a substance to move so fast that the molecules 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

22. Define boiling.

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

Heat added
Movement of molecules increases
Pressure increases
When water reaches 100 degrees Celsius, vapor bubbles form

23. Define freezing.

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

Heat removed
Molecules slow down
Water becomes a solid at 0 degrees Celsius

24. Define ground water.

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

25. Define steam.

When water boils, some of the molecules escape into the air becoming water vapor. This process is called evaporation. 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

26. Define water vapor.

Water in a gaseous state which is invisible to the eye. The vapor is invisible due to the great distance between the water molecules.

Different form of water
Gas
Invisible
Great distance between water molecules

# APPENDIX C

# SOUND UNDERSTANDING INTERVIEW

SOUND UNDERSTANDINGS INTERVIEW Name ____________________________

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

Heat energy is added ____ origin # ____
Heat energy becomes molecular kinetic energy ____
Molecules move faster ____ ______________
Molecular attraction is lessened ____
Some fast moving molecules on the surface escape ____
Liquid water becomes water vapor ____

Other____________________________________________________________________________

_________________________________________________________________________________

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?

Heat energy is added ____ origin #____
Heat energy becomes molecular kinetic energy ____
Molecules move faster ____ _____________
Molecules move farther apart ____
Molecular attraction is lessened ____
Fast moving surface molecules escape ____
Water has a new state: gas (water vapor) ____
Fan blows the water vapor away ____
Air around paper towel contains fewer water molecules ____
More water molecules can escape from the spot ____

Other____________________________________________________________________________

_________________________________________________________________________________

3. What causes the clothes to dry? (Will be shown a picture of clothes drying on a clothes line.)

Sun provides heat ____ origin #____
Heat becomes molecular kinetic energy ____
Molecules move faster ____ _____________
Molecules move farther apart ____
Molecular attraction is lessened ____
Surface molecules escape ____
Water has a new state: gas (water vapor) ____
Wind carries water vapor away ____
Surrounding air less saturated with water vapor ____
More surface molecules can escape ____

Other____________________________________________________________________________

_________________________________________________________________________________

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

No ____ origin #____
Water vapor is invisible. ____

____________

Other________________________________________________________________

________________________________________________________________________

—

5. Can we still call it water?

Yes ____ origin #____
But, it is in a gaseous form ____

____________

Other________________________________________________________________

________________________________________________________________________

6. How are clouds formed?

Sun's heat becomes molecular kinetic energy ____ origin #____
Energy cause water evaporation ____
Warm air expands and rises ____ ____________
Air pressure decreases as the water vapor rises ____
Water vapor expands ____
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 _____

Other ________________________________________________________________

________________________________________________________________________

7. How do clouds get up in the sky?

Air near surface heated and cooled unequally ____ origin #____
Air above land warmer than air above water
in the daytime ____ ____________
Warm air expands and becomes lighter ____
Cool air pushes warm air upward ____

Other ________________________________________________________________

________________________________________________________________________

8. What makes it rain? (Does it rain everytime clouds are in the sky?)

Air contains all the water vapor it can hold (saturated) ____ origin #____
Temperature of air falls below dew point ____ ____________
Particles present in the air ____
Water molecules attach to the particles ____
The cluster of molecules become large enough to overcome updraft of air ____
Gravity will pull clusters to the earth ____

Other ______________________________________________________________

______________________________________________________________________

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

Water vapor in air ____ origin #____
Molecules collide with sides of jar ____
Sides of jar are below dew point ____ ____________
Heat is removed from air next to jar ____
Molecules slow down ____
Molecules are more attracted to one another ____
Condensation occurs on the sides of the jar ____

Other ______________________________________________________________

______________________________________________________________________

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

Water (over 70%, less than 75%) 71% ____ origin #____

____________

Other______________________________________________________________

______________________________________________________________________

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

Could ____
Amount of water remains constant_____ origin #____
Pollution_____
Purification of water_____ ____________
Water conservation_____

Other______________________________________________________________

______________________________________________________________________

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

To a septic tank_____ origin #_____
Sedimentation_____
Filtered through rocks and soil_____ ____________
To a water purification plant_____
Released unclean into lakes or rivers_____

Other________________________________________________________________

____________________________________________________________________

13. How would you get it clean?

Water purification plant_____ origin #_____
Filters & sedimentation_____
Bacteria which eats waste____ ____________
Chemicals_____
Boiling_____
Distillation/Evaporation_____
Flowing through soil and rocks_____

Other________________________________________________________________

____________________________________________________________________

14. What is a well?

Ground water_____ origin #_____
Layer of solid, nonporous rock_____
Water table_____ ____________
Hole deeper than water table_____

Other________________________________________________________________

____________________________________________________________________

15. Can you drink from any well? origin #_____

No_____ ____________

Other________________________________________________________________

____________________________________________________________________

16. Why or why not? origins #____

Not if pollutants are present. Pollutants may include: ____________
Heavy metals: mercury, lead, cadmium, etc._____
Pesticides & herbicides_____
Oil_____
Synthetic detergents (phosphates)_____
Bacteria or virus (feces & urine of humans or animals)_____
Acid rain_____

Other______________________________________________________________________

___________________________________________________________________________

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

No, not if pollutants are present_____ origin #_____

Pollutants may include:

Heavy metals_____ _____________

Pesticides & herbicides_____

Oil_____

Synthetic detergents_____

Bacteria or virus_____

Acid rain_____

Other ______________________________________________________________________

___________________________________________________________________________

18. Define evaporation. origins #____

_____________

Heat increases kinetic molecular energy_____

Molecules move fast when heat is absorbed_____

Molecules move farther apart ____

Molecular attraction is lessened _____

Some surface molecules escape from liquid_____

Liquid water becomes water vapor_____

Water vapor is invisible_____

Other ______________________________________________________________________

___________________________________________________________________________

19. Define condensation. origins #____

_____________

Changing from the gas form to the liquid form of water_____

Heat is taken away _____

Molecules slow down _____

Molecular attraction increases _____

Water vapor becomes liquid water_____

Other______________________________________________________________________

___________________________________________________________________________

20. Define gravity. origin #_____

_____________

Force_____

Particles of matter are pulled toward each other_____

Matter on or near the earth is pulled toward the center of the Earth_____

Other ______________________________________________________________

______________________________________________________________

21. Define melting. origin #_____

Kinetic molecular energy has been increased by adding a heat source_____ ____________
Molecules move faster ____
Molecules move farther apart_____
Molecules no longer hold their orderly arrangement_____
Solid looses its shape_____

Other______________________________________________________________

______________________________________________________________

22. Define boiling. origin #_____

Heat added_____ ____________
Movement of molecules increases_____
Pressure increases_____
Water reaches 100 degrees Celsius____
Vapor bubbles form_____

Other ______________________________________________________________

______________________________________________________________

23. Define freezing. origin #_____

Heat removed______ ____________
Molecules slow down_____
Molecular attraction increases____
Water becomes a solid at 0 degrees Celsius_____ 32 degrees Fahrenheit____

Other______________________________________________________________

______________________________________________________________

24. Define ground water. origin #_____

Water beneath the earth's surface_____ ____________
Held in the soil and rock spaces_____

Other
______________________________________________________________

______________________________________________________________

25. Define steam.

Evaporation_____ origin #_____
Water vapor cooled by surrounding air_____
Condenses_____ ______________
Becomes visible droplets_____

Other______________________________________________________________________

___________________________________________________________________________

26. Define water vapor.

Different form of water_____ origin #_____
Gas_____
Invisible_____ ______________
Great distance between water molecules_____

Other______________________________________________________________________

___________________________________________________________________________

APPENDIX D

INFORMATION SHEET

Information Sheet

1. Your college classification:
   a. Freshman, b. Sophmore, c. Junior, d. Senior, e. Other

2. Your age
   a. 17 - 20, b. 20 - 25, c. 25 - 30, d. older

3. Your gender (sex)
   a. male, b. female

4. Which university are you attending now?
   a. John Brown University, b. Oklahoma State University

5. How many earth and physical science courses (geology, astronomy, meteorology, oceanography, mineralogy, geophysics, or geochemistry.) did you complete in high school?
   a. None, b. One, c. Two, d. Three, e. Four

6. How many chemistry courses did you complete in high school?
   a. None, b. One, c. Two, d. Three, e. Four

7. How many physics courses did you complete in high school?
   a. None, b. One, c. Two, d. Three, e. Four

8. How many biology courses did you complete in high school?
   a. None, b. One, c. Two, d. Three, e. Four

9. How many earth and physical science courses (geology, astronomy, meteorology, oceanography, mineralogy, geophysics, or geochemistry.) have you completed in college?
   a. None, b. One, c. Two, d. Three, e. Four

10. How many chemistry courses have you completed in college?
    a. None, b. One, c. Two, d. Three, e. Four

11. How many physics courses have you completed in college?
    a. None, b. One, c. Two, d. Three, e. Four

12. How many biology courses have you completed in college?
    a. None, b. One, c. Two, d. Three, e. Four

13. Have you completed a science course designated particularly for elementary teachers?
    a. No, b. Yes

14. Have you taught the water cycle or water related concepts?
    a. No, b. one lesson, c. two to five lessons, d. six or more

15. Have you taken or do you intend to take more than the required science hours for your degree?
    a. No, b. Yes

16. At what level would you prefer to teach?
    a. primary (K-3), b. intermediate (4-6), c. K-6

APPENDIX E

SPECIFIC MISUNDERSTANDINGS

Sound Understanding Interview questions and the interviewees' misconceptions

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

a. Bubbles in boiling water are H, O, or $CO_2$
b. Bubbles in boiling water are air
c. Molecules enlarge
d. Colliding molecules produce more energy
e. Other

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?

a. Breaks water into H, O, and/or $CO_2$
b. Heat draws moisture
c. Wind forces water out of clothes
d. Molecular collisions increase molecular speed
e. Other

3. What causes the clothes to dry? (Will be shown a picture of clothes drying on a clothes line.)

a. Breaks water into H, O, and/or $CO_2$
b. Heat draws or absorbs moisture
c. Wind adds energy to molecules
d. Molecule gets lighter
e. Other

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

a. Molecules or atoms become too small to be seen
b. Could see if really hot (temperature)
c. Molecules moving too fast
d. Like a gas but not a gas
e. Other

5. Can we still call it water?

a. No, different substance ( H, O, $CO_2$)
b. No, water is gone
c. No, because you can't feel (you can feel water)
d. No, molecular structure changes
e. Other

6. How are clouds formed?

a. H & O or H & $CO_2$ reunite
b. Gases in the air and moist in the earth come together
c. Pressure pushes molecules together
d. Gravity pulls air up
e. Other

7. How do clouds get up in the sky?

a. The denser the cloud, the lower it is
b. Particles and water are up in the sky
c. Differences in air pressure
d. God puts them there
e. Other

8. What makes it rain? (Does it rain everytime clouds are in the sky?)

a. H & O molecules build up and combine
b. Temperature gets warm
c. H & L pressure coming together causes friction
d. Attraction caused by lack of electrons
e. Other

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

a. H & O or O & CO2 bond
b. Coldness attracts molecules
c. Water (molecules) pentrate through jar
d. Moisture came from ice
e. Other

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

a. 3/4
b. 2/3
c. 90's
d. Other

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

a. No, watercycle is a continuous process
b. No, can always supply purified water
c. Yes, because cannot recycle salt water
d. Yes, God will supply
e. Other

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

a. Everything stays in septic tank
b. Septic tank contents are piped to sewage plant
c. Sewer pipes lead directly into ground or sea
d. Sewage just sets in ponds
e. Other

13. How would you get it clean?
a. Moving water is clean
b. Add clean water to polluted water
c. Use salt and lime to purify
d. Use minerals to purify
e. Other

14. What is a well?

a. Must find pocket of water
b. The deeper the well, the cleaner the water
c. All water is flowing underground
d. Moisture is always 1 to 2 ft. underground
e. Other

15. Can you drink from any well?

a. Yes
b. Yes, most of the water is not contaminated
c. Other

16. Why or why not?

a. Minerals
b. Rust
c. Dirt
d. Wells have clean water
e. Other

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

a. Pollutants included mud
b. " " minerals
c. " " salt
d. Would rather drink from a lake that does not have animals living in it rather than one that does
e. Other

18. Define evaporation.

a. Water becomes H, O, and/or CO2
b. Heat absorbs water
c. Liquid water becomes steam
d. Molecules expand and become lighter
e. Other

19. Define condensation.

a. H & O (or CO2 joins one of them) come together
b. Chemical reaction
c. Molecules become smaller and/or heavier
d. When moisture and heat mix
e. Other

20. Define gravity.

a. No gravity in outerspace
b. Gravity created by Earth's rotation
c. Gravity caused by atmospheric pressure
d. No atmosphere, no gravity
e. Other

21. Define melting.

    a. Molecules get smaller
    b. Breaks down particles
    c. Fast movement of molecules causes friction which creates more heat
    d. Chemical reaction
    e. Other

22. Define boiling.

    a. Bubbles are air
    b. Bubbles are oxygen
    c. Bubbles are CO2
    d. Molecules get bigger
    e. Other

23. Define freezing.

    a. Molecules stop moving
    b. Molecular structure changes
    c. Molecules change size
    d. Reverse F and C temperatures
    e. Other

24. Define ground water.

    a. Clean or clear water
    b. Mass or pocket of water only
    c. Water above ground
    d. Water that flows underground
    e. Other

25. Define steam.

    a. Gas form/water vapor
    b. Requires more heat than water vapor
    c. Molecules get bigger
    d. Collection of O or CO2
    e. Other

26. Define water vapor.

    a. Same as steam
    b. Result of slow evaporation
    c. Can see water vapor
    d. Molecules or atoms become too small to be seen
    e. Other

# APPENDIX F

# WATER CYCLE ASSESSMENT TEST

WCAT Questions and answers

1. If a small saucer of water is placed on a window sill in the sunlight, after awhile the saucer will be dry. What happens to the water that was in the saucer?
   a. It goes into the saucer.
   b. It just dries up and no longer exists as anything.
   c. It changes into oxygen and hydrogen in the air.
x  d. It goes into the air as very small bits of water.

2. What will happen to the water particles in a pan of water sitting on the hot burner of a stove? The water particles
   a. fill with bubbles.
x  b. begin moving faster.
   c. stop moving.
   d. begin to move slower.

3. When a pan of water boils there are bubbles in the water. What are the bubbles made of?
   a. Air
x  b. Water vapor
   c. Heat
   d. Oxygen or hydrogen

4. What must be done to change a solid to a liquid or a liquid to a gas?
x  a. Energy must be added to make the changes, usually heat energy.
   b. Energy must be taken away to make the change.
   c. Energy must be the same to make the change.
   d. Nothing, the change just happens.

5. If enough heat is added to liquid water, the water
   a. condenses.
   b. contracts.
x  c. becomes a gas.
   d. becomes a solid.

6. A solid changes to a liquid when
   a. water boils.
x  b. ice cream melts.
   c. a puddle dries.
   d. coffee perks.

7. For rain to result from a cloud, which must occur?
   a. Add heat only.
   b. Take away heat only.
x  c. Add moisture and take away heat.
   d. Add moisture only.

8. Water droplets can form on the outside of a closed jar that contains an ice cold drink. Where do the water droplets come from?
   a. Come from the cold water inside the glass.
   b. Come through the glass and form on the outside of the glass.
   c. Evaporate over the top of the glass and drip down the side of the glass.
x  d. Come from the air outside the glass.

9. When millions of tiny drops of water and bits of dust float together in the air,
x a. clouds are formed.
b. the water cycle ends.
c. snowflakes fall.
d. dew is formed.

10. What must be done to change a liquid to a solid?
x a. Energy must be taken away.
b. Energy must be added.
c. Energy must be the same.
d. Energy is neither added or taken away, it just changes.

11. What causes wet clothes to dry on the line?
a. The movement of water particles
b. The wind blowing
c. The sun shining
x d. All of the above

12. As damp (not dripping wet) clothes dry, where does the water go?
a. It drips out.
b. It goes into the ground.
x c. It goes into the air.
d. It just disappears.

13. Most fresh water on earth is stored as water in
a. the atmosphere.
b. the oceans.
c. the ground.
x d. ice.

14. If you lived in North America before the white man came, from which of the following could you most safely drink water?
x a. A stream with fish, frogs, and plants
b. A sewer
c. A stream with no fish, frogs, and plants
d. An ocean

15. Evaporation
a. The changing of a gas to a liquid
x b. The changing of a liquid to a gas
c. The changing of a solid to a liquid
d. The changing of a liquid to a solid

16. Condensation
x a. The changing of a gas to a liquid
b. The changing of a liquid to a gas
c. The changing of a solid to a liquid
d. The changing of a liquid to a solid

17. Gravity is the force of one object
a. pushing another object.
b. falling on another.
c. moving another object.
x d. pulling another object.

18. Melting
    a. Moving particles slow down and get closer together.
    b. Moving particles stop moving and drift apart.
    c. Moving particles disappear.
x   d. Moving particles speed up and move farther apart.

19. Boiling
    a. Moving particles slow down and get closer together.
    b. Moving particles stop moving and drift apart.
    c. Moving particles disappear.
x   d. Moving particles speed up and move farther apart.

20. Freezing
    a. Moving particles slow down and get closer together.
    b. Moving particles stop moving and drift apart.
    c. Moving particles disappear.
x   d. Moving particles slow down and move farther apart.

21. Ground Water
x   a. Water found underground in porous rock and gravel.
    b. Water found in small ponds.
    c. Any water found on the surface of the ground.
    d. Water from natural springs.

22. Steam
    a. Any vapor, fume, or mist
    b. Solid particles in a gas
x   c. Water in gas form which is condensing
    d. Water that has disappeared never to be seen again

23. Water vapor
    a. Any vapor, fume, or mist
    b. Solid particles in a gas
x   c. Water in gas form
    d. Water that has disappeared

Extra question:
24. Well
    a. Deep hole dug into ground water
    b. Deep hole dug into under ground river or lake
x   c. Hole dug below water table
    d. Hole dug into clean flowing under ground water

APPENDIX G

LIST OF POSSIBLE ORIGINS

# LIST OF POSSIBLE ORIGINS

What is the source of your information?

1. Did you guess this answer?
2. Did someone tell you this answer sometime?

   Teacher, father, mother, brother, sister

   Other________________________________
3. Did you read this somewhere?

   Book, comic, newspaper

   Other________________________________
4. Did you learn this from television? radio?
5. Is this the result of your own observation?
6. Did you (just) work this out for yourself?

(Trembath & Barufaldi, 1981)

VITA

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Doctor of Education

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