THE DEVELOPMENT AND VALIDATION OF A THREE-TIER DIAGNOSTIC TEST MEASURING PRE-SERVICE ELEMENTARY EDUCATION AND SECONDARY SCIENCE TEACHERS' UNDERSTANDING OF THE WATER CYCLE

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By

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The undersigned, appointed by the Dean of the Graduate School, have examined the dissertation entitled

THE DEVELOPMENT AND VALIDATION OF A THREE-TIER DIAGNOSTIC TEST MEASURING PRE-SERVICE ELEMENTARY EDUCATION AND SECONDARY SCIENCE TEACHERS' UNDERSTANDING OF THE WATER CYCLE

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A candidate for the degree of

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And hereby certify that, in their opinion, it is worthy of acceptance.

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For Mom, Dad, Max, Nick, and Heidi:
Thanks for believing.

Love, Dane

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ABSTRACT

The main goal of this research study was to develop and validate a three-tier diagnostic test to determine pre-service teachers' (PSTs) conceptual knowledge of the water cycle. For a three-tier diagnostic test, the first tier assesses content knowledge; in the second tier, a reason is selected for the content answer; and the third tier allows test-takers to select how confident they are in their answers for the first two tiers. The second goal of this study was to diagnose any alternative conceptions PSTs might have about the water cycle.

The Water Cycle Diagnostic Test (WCDT) was developed using the theoretical framework by Treagust (1986, 1988, and 1995), and in similar studies that developed diagnostic tests (e.g., Calean & Subramaniam, 2010a; Odom & Barrow, 2007; Pesman & Eryilmaz, 2010). The final instrument consisted of 15 items along with a demographic survey that examined PSTs' weather-related experiences that may or may not have affected the PSTs' understanding of the water cycle. The WCDT was administered to 77 PSTs enrolled in science methods courses during the fall of 2012. Among the 77 participants, 37 of the PSTs were enrolled in elementary education (EPST) and 40 in secondary science (SPST). Using exploratory factor analysis, five categories were factored out for the WCDT: Phase Change of Water; Condensation and Storage; Clouds; Global Climate Change; and Movement through the Water Cycle. Analysis of the PSTs' responses demonstrated acceptable reliability ($\alpha = 0.62$) for the instrument, and acceptable difficulty indices and discrimination indices for 12 of the items.

Analysis indicated that the majority of the PSTs had a limited understanding of the water cycle. Of the PSTs sampled, SPSTs were significantly more confident in their answers' on the WCDT than the EPSTs. Completion of an undergraduate atmospheric science and/or meteorology course, as well as a higher interest in listening and/or viewing weather-related programs, resulted in PSTs having greater understanding and confidence in their answers on the WCDT. The analysis of the PSTs' responses revealed 49 potential alternative conceptions and areas where PSTs' lack of knowledge was revealed from the WCDT.

CHAPTER ONE

INTRODUCTION

Water is a necessary ingredient for life here on Earth. With global human population approaching eight billion in the next decade, the supply, the demand, and the ability to obtain fresh water will be a high priority for all nations. Even though water is so vital for life, most individuals have a very inadequate or limited understanding about water as a scientific phenomenon (Henriques, 2000; Phillips, 1991). Related topics such as weather and climate cannot be adequately explained without a basic understanding of the cycling of water in and out of the atmosphere and its ability to transmit heat from the equator to the Polar Regions. Moreover, the scientific issue of global climate change cannot be fully understood without a fundamental understanding of the water cycle. For example, with mass media always talking about carbon dioxide’s involvement in the warming of our atmosphere, it is no wonder that most people think that carbon dioxide is the primary greenhouse gas, not water vapor. Educating everyone about climate change should be a high worldwide priority. However, do our future teachers have sufficient understanding of water and the water cycle to reach the necessary achievement level for scientific literacy?

Need of the Study

In *Science for All Americans* (Rutherford & Ahlgren, 1989), the American Association for the Advancement of Science (AAAS) stated that having a fundamental understanding of the water cycle is a necessary ingredient for all Americans in achieving the goal of scientific literacy:

> The cycling of water in and out of the atmosphere plays an important part in determining climatic patterns-evaporating from the surface, rising and cooling,

> condensing into clouds and then into snow or rain, and falling again to the surface, where it collects in rivers, lakes, and porous layers of rock. There are also large areas on the earth's surface covered by thick ice (such as Antarctica), which interacts with the atmosphere and oceans in affecting worldwide variations in climate, (p. 43).

That students should have a strong understanding of the water cycle by the time they graduate from high school is further reiterated in the *Benchmarks for Science Literacy* (AAAS, 1993), the *National Science Education Standards* (*NSES*), (National Research Council [NRC], 1996) and the new draft of the *Next Generation Science Standards (NGSS),* (Achieve, Inc., 2012). Moreover, the *Atlas for Science Literacy: Volume 2* (AAAS, 2007) goes on to state the following as to how and when the water cycle should be taught:

> The progression of understanding begins in the elementary grades with observations about heat transfer, changes in water from one state to another, and changes in weather over the course of a day and over the course of seasons. By middle school, the focus is on the water cycle, patterns of change in temperature, and the notion of climate change. In high school, seasons and winds and the water cycle are related to gravity and the earth's rotation, and climate change is related to natural causes and human activities, (p. 20).

If all of the national and state standards are taught and learned as planned, then science education faculty should not be seeing undergraduates with major scientific misconceptions, especially those concerning the water cycle. According to Brody (1993), "Earth systems knowledge related to water centers around the concept of the water cycle which is poorly understood by all students," (p. 2). The reason for this might simply be because most undergraduates have not learned about the water cycle since middle or junior high school Earth Science courses or other related classes.

Educators know that their students come into their classrooms with a considerable amount of understanding of the natural world because of their prior life experiences. But, are these understandings correct? No matter what you want to call these misguided understandings -- alternative conceptions, naïve conceptions, or children's science views (Wandersee, Mintzes, & Novak, 1994) -- they are misconceptions that need to be dealt with by the educational community because these "understandings" are a roadblock to this country's goal of achieving scientific literacy.

Water is an essential ingredient for life, and having a conceptual understanding of the water cycle has been documented by a variety of educational policy documents as a necessity for obtaining scientific literacy from *Science for All Americans* (Rutherford & Ahlgren, 1989) to the recently developed *A Framework for K -12 Science Education* (NRC, 2012) which has lead to the new *NGSS* (Achieve, Inc., 2013). Knowledge of the water cycle plays an integral role in the *NGSS's* disciplinary core and component ideas in the Earth and Space Sciences including: *Earth Materials and Systems; The Roles of Water in the Earth's Surface Processes; Weather and Climate; Biogeology; Natural Resources; Natural Hazards; Human Impacts on Earth Systems*; and *Global Climate Change* for students to learn and to be assessed. The water cycle is not merely just the processes of evaporation, condensation, and precipitation, but much more (AMS, 2001).

A significant problem for teachers is that students do not want to give up these alternative conceptions because many of these conceptions were taught by their previous teachers or instilled by reading textbooks (Duit & Treagust, 1995). Therefore, teachers need to take into account their students' current understanding of a concept before teaching begins (Driver & Easley, 1978). This constructivist (Piaget, 1950) view of student learning is important because teachers need to create new experiences that will accommodate or change a student's existing conceptual framework, rather than assimilate the framework, which possibly would not change the student's misconception.

There are a limited number of scientific studies which have examined students' misunderstandings of the water cycle or components of the water cycle (e.g., Bar, 1989; Bar & Galili, 1994; Bar & Travis, 1991; Ben-zvi-Assarf & Orion, 2005; Cardak, 2009; Russell, Harlen, & Watt, 1989; Shepardson et al., 2008;Taiwo, 1999), but generally these studies have focused upon students in grades K-12, and not upon pre-service teachers or in-service teachers who are currently teaching the water cycle. With all the research focusing on potential students' misconceptions, undergraduate educators and science education researchers need to develop ways of identifying scientific misconceptions that pre-service teachers, both at the elementary and secondary levels, may have before these teachers go into our schools to educate our youth. Schoon (1995) stated, "Understanding how alternative conceptions are formed can make it easier for classroom teachers to help their students uncover their own alternative conceptions. Teachers, however, cannot be expected to help children with alternative conceptions if they hold these alternative conceptions themselves," (p. 27). Evaluating these possible alternative conceptions of pre-service teachers (PSTs) may enable science educators and researchers in finding ways to strengthen undergraduate teacher education programs. In addition, it is imperative to assess PSTs' understanding of fundamental scientific concepts before they leave university programs so that these alternative conceptions are not passed on to their future students.

Assessment of Student Learning

In 2001, NRC used the term, "ubiquitous" when talking about assessments (p.1). Since the enactment of the federal mandate No Child Left Behind (NCLB) in 2001, testing, regardless of subject area, is foremost in the minds of educators. This explosion in testing has put an additional pressure for increasing educational achievement and accountability not only on students and teachers, but on local school districts, state education departments, and higher education. Assessment, whether based on summative or formative evaluations, is deemed a vital part of the everyday communication exchange between students and teachers to monitor the growth of students' learning within the classroom.

Today, most of those assessments are considered by many K-12 classroom teachers as high-stakes because the results are tied to school and district accreditation, student promotion, and teacher performance evaluations, but these tests are primarily considered to be summative. According to the NRC (1999), assessments serve the following purposes in the educational setting:

> One purpose is to monitor educational progress or improvement. Educators, policymakers, parents, and the public want to know how much students are learning compared to standards of performance or to their peers. This purpose, often called *summative* assessment, is becoming more significant as states and school districts invest more resources in educational reform.
>
> A second purpose is to provide teachers and students with feedback. The teachers can use the feedback to revise their classroom practices, and the students can use the feedback to monitor their own learning. This purpose, often called *formative* assessment, is also receiving greater attention with the spread of new teaching methods.
>
> A third purpose of assessment is to drive changes in practice and policy by holding people accountable for achieving the desired reforms. This purpose, called *accountability* assessment, is very much in the forefront as states and

> school districts design systems that attach strong incentives and sanctions to performance on state and local assessments (p.3).

Summative assessments are usually given at the end of a chapter of study, unit, or a course to provide feedback to the student, teacher, parents, districts, etc. about students' academic progress and achievement, and as in the case of NCLB, accreditation (Abell & Volkmann, 2006). While these summative assessments are getting the most attention, it is the formative assessments that provide the foundational base for monitoring day-to-day student progress and learning.

Formative assessments give teachers information about students' knowledge and what students can and cannot accomplish at a particular moment in time during classroom instruction (Shavelson et al., 2008). This type of assessment also helps teachers improve and guide their own instruction, and allows teachers to check if a student has a misunderstanding about the content and/or topic. In addition, they can continually monitor the student's progress toward learning that concept. There are a variety of ways that a classroom teacher can conduct formative assessments to determine students' conceptual knowledge of a subject, such as concept mapping (Novak, 2002, 1995; Novak & Gowin, 1984; Ruiz-Primo, 2000), interviews (Bell, 1995; Carr, 1996; Posner & Gertzog, 1982), and multiple choice diagnostic tests (Treagust, 1986, 1988, and 1995). There is an increased awareness on college campuses to improve classroom instruction through the use of formative assessments. Historically, faculty would lecture for an hour and students took copious amounts of notes, and then had only two examinations to justify the grade: the mid-term and the final. Assessments were very summative in nature. Moreover, professors did not talk to the students, and the students did not talk to the instructor during class, so assessing formatively was completely absent. One of the biggest higher education changes since the middle of the 1980's has been the increased development and use of diagnostic tier tests (DTTs) and concept inventories (CIs). Both DTTs and CIs serve the same formative purpose: first, to diagnose conceptual problems a student might have about a topic, and second to monitor the improvement in student learning.

Scientific DTTs and CIs are criterion-referenced tests that are usually designed to evaluate student's understanding of current accepted scientific concepts. These criterion-referenced assessments are developed around a set of recognized performance standards in which students are compared. Achievement is based upon students obtaining a certain level of mastery, sometimes called a cut-score. If students reaches or scores above the cut-score, then they are considered to have mastered those standards. Many of the high-stakes tests now found in most states on the K-12 level are criterion-referenced because these assessments are developed around national and state standards, guidelines, and/or proficiencies. In norm-referenced tests, students are compared to other students taking the assessment (Murphy & Davidshofer, 2005). Notable norm-referenced tests include the SAT, ACT, and the GRE, but it is important to remember that the above high-stakes examinations and norm-referenced assessments are not considered formative in nature.

Recently, there has been some confusion in the science education community about the differences between DTTs and CIs, but when one examines those assessments, there is no problem distinguishing one assessment from the other. DTTs are very topic-specific in terms of what is being assessed. Although both DDTs and CIs usually follow the same basic format in their development using a framework developed by Treagust (1986, 1988, and 1995), DTTs' unique tiering allows educators to better diagnose students' alternative conceptions. DTTs' first tier, called the content tier, requires students to respond to a content knowledge question and the second tier, called the reason tier, requires students to select an explanation as to why they selected their answer to the first tier. For researchers, two-tier tests allow instructors to identify whether or not a wrong answer in the first tier is due to lack of knowledge or a misconception, as well as whether or not a correct answer of the first tier was due to the student actually understanding the scientific concept.

Most DTTs are two-tier, but there are currently a few three-tier DTTs (e.g., Diffusion and Osmosis, Odom & Barrow, 2007; Nature and Propagation of Waves, Caleon & Subramaniam, 2010a; Simple Electric Circuits, Pesman & Eryilmaz, 2010), and one four-tier (e.g., Properties and Propagation of Mechanical Waves, Caleon & Subramaniam, 2010b). Three-tier and four-tier assessments involve the use of confidence ratings, a confidence tier, which allows students to rate their strength of confidence in their answers to the first and second tier levels. DTTs are most prevalent in Biology, Chemistry, and Physics, but we also see some two-tier testing in other content areas such as the Nature of Science, the Learning Cycle, and Scientific Measurement that are not associated with CIs. At this time, there are no published or developed DTTs available in the geosciences. Overall, the lack of assessments in the geosciences provides a bountiful area for potential science education research.

CIs are more commonly found in mathematics, the sciences, and engineering, but can be applied to any subject area. The first widely-disseminated science CI was the Force Concept Inventory (FCI, Hestenes, Wells, & Swackhamer, 1992), which assesses the basic understanding of Newtonian physics. Currently, Physics has the greatest number of developed CIs, but within the last four years, Biology's number of CIs has expanded from two published inventories to eight. The Geosciences have the least, with two published CIs, but it is important to remember that the geosciences have lagged far behind many of the other science disciplines when it comes to science education research (Libarkin & Anderson, 2005). Lewis and Baker (2010) called for more researchers in science education to focus upon the geosciences: "We argue that such research studies [Geosciences] are necessary to inform science education policy and advance scientific literacy" (p.121).

CIs usually cover a broad area of one science discipline (e.g., Biology Concept Inventory [BCI], Klymkowsky & Garvin-Doxas, 2008; Chemistry Concept Inventory [ChCI], Pavelich et al., 2004), but lately many CIs have been developed to assess more specific concepts within a science discipline (e.g., Volcanic Concept Survey [VCS], Parham et al., 2010; Greenhouse Effect Concept Inventory [GECI], Keller, 2006). Most of these CIs are developed through extensive research that involves using a multiple-choice format so that the test can be given to large number of students at one time, and scoring of the test can be done objectively and quickly. Also, many of these assessments are given as pre- and posttest to determine the amount of learning that has occurred or whether or not a modification in the classroom instruction has caused a changed in learning.

Purpose of the Study

The goal of this research study was to develop and validate a three-tier diagnostic test on the water cycle that can be used by science content and methods educators to quickly determine pre-service elementary (EPSTs) and secondary science teachers'

(SPSTs) conceptual knowledge of the water cycle, to diagnose their alternative conceptions, and to see how strongly these alternative conceptions are being held by the study's participants. The diagnosis of these alternative conceptions will hopefully lead to the development of more effective teaching strategies and interventions that will help reduce some of the barriers of reaching scientific literacy. This study requires the development of a valid Water Cycle Diagnostic Test (WCDT).

Below is a summary of the purpose of the study:

1. To develop a reliable instrument that will identify EPSTs' and SPSTs' alternative conceptions about the water cycle.
2. To validate the instrument so that it can be used in the assessment of accurate conceptions about the water cycle.
3. To identify EPSTs and SPSTs' alternative conceptions about the water cycle.
4. To determine whether EPSTs' and SPSTs differ in their conceptual understanding concerning the water cycle.
5. To determine whether there is a relationship between the last time EPSTs and SPSTs studied the water cycle and their score on the WCDT.
6. To determine if having a strong interest in the weather and/or experiencing a severe weather phenomena has an effect on conceptual understanding of the water cycle.

Definition of Key Terms

For this research study, the following terms are defined as follows:

Alternative Conception

Alternative conception refers to a person's understanding of a concept that differs from the currently accepted scientific evidence. These alternative conceptions may hinder the student's ability to learn new scientific knowledge. Other terms such as a "misconception," "naïve conception," "children's science view," and/or "preconceived idea" or "notion" can be used in research literature as synonyms for alternative conception.

Alternative Response

On a diagnostic tiered-test, it is an answer combination other than the scientifically acceptable combination that may represent a partial level of understanding.

Certainty of Response Index (CRI)

Using a Likkert-type scale, students will provide the degree of confidence they have in the correctness of their answers for the first two-tiers of the WCDT. This answer will be recorded in the third tier of the WCDT.

College Base Academic Subjects Examination (CBASE)

CBASE is a criterion-referenced achievement test that all undergraduate education majors need to take as part of the process for obtaining host state teacher certification. Usually taken after the second year in their program, students are assessed in English, mathematics, science, and social studies. Test scores range from 40 to 560 points, and are also described descriptively as being high, medium, or low. Students who fail to reach the needed cut-score (235 points) for passing may continue to retake those portions of the

CBASE for up to two years after they originally completed the CBASE. In this study, CBASE scores will be used to examine if there is a correlation with the WCDT.

Concept

A concept is a "perceived regularity in events or objects, or records of events or objects, designated by a label," (Novak, 1995, p. 229).

Concept Map

A concept map is a structural graphic representation for organizing and representing knowledge (Novak, 1995).

Condensation

Condensation is the physical process of converting water vapor into water. During condensation, water vapor molecules release latent heat to the environment causing a warming effect in the atmosphere and uplift as clouds form.

Confidence

A person's ability to be certain or assured they have selected an answer correctly. There are degrees of certainty ranging from guessing to very confident on the WCDT. A 4-point Likkert scale will be utilized for the WCDT.

Distractors

Alternative answers within the list of possible responses to the question. They are plausible solutions to the question that may reveal students' alternative conceptions.

Evaporation

Evaporation is the physical process of converting water to water vapor. This includes evaporation from surfaces of different bodies of water such as oceans, lakes, and rivers, but also from the soil and the surfaces of plants. The process of evaporation requires absorbing heat from water or surrounding molecules. This absorption of "latent" heat by the atmosphere causes a cooling effect.

Groundwater

Groundwater is water that seeps deeply into earth and may fill the spaces between the particles of rocks and soils. Groundwater flows very slowly into subsurface environments from areas of recharge to areas of discharge.

Item Difficulty

Item difficulty measures the proportion of participants who answered a test item correctly. The WCDT will use the statistical index called Delta (Δ) to calculate item difficulty. Delta is defined as 13 + 4z, where z is the normal deviation of the number of participants that selected an item correctly. Delta values can range from 6.0 to over 20.0, with 6.0 being considered very easy to over 20.0 being considered an extremely hard test item. The overall goal was to have a Δ of 13.0 for the WCDT.

Item Discrimination

Item discrimination examines the ability of an assessment item to differentiate between students who are knowledgeable about a topic and those who are not. For the WCDT, point-biserial correlation (r_{pbis}) will be the statistical index used to calculate item discrimination. An overall point-biserial value of 0.20 was established for this study.

Precipitation

Precipitation is a physical process during which any form of water falls from a cloud and reaches the ground. Precipitation can take many forms: mist, rain, drizzle, snow, sleet, and hail.

Pre-service Teachers (PSTs)

An undergraduate student who has declared education as a major but has not graduated or gained state certification to teach. For this study, participants will be from EPSTs and SPSTs.

Propositional Knowledge Statements (PKS)

A PKS is the connection of two or more concepts linked together by words in a semantic unit.

Reliability

Reliability of an assessment is the consistency measurement or whether or not a test instrument measures the same way each time it is used under the same conditions with the same population of subjects.

Runoff

Water that flows across land surfaces to rivers and/or streams, and eventually back to the ocean. This is dependent upon rainfall intensity, vegetation, topography, and physical properties of the land surface.

Three-Tier Test Item

A DTT that has three levels of assessment. The first tier requires respondents to answer questions about their content knowledge of a topic. The second tier requires students to select a reason for their content answer. For the third tier, students rate their confidence level in regards to their selected answers in the first two tiers.

Transpiration

Transpiration is a living process whereby water that is absorbed from the soil by plant roots eventually escapes as vapor through tiny pores (stomata) on the surface of green leaves. Transpiration from plants adds to the total amount of water vapor found in the atmosphere.

Two-Tier Test

A DTT with two tiers of assessing a student's conceptual understanding and diagnosing alternative conceptions. This includes a content response for the first tier, and a reason response for the second tier to their selection for the first tier.

Validity

Validity of an assessment is the level in which a test measures what it claims to measure. Validating the WCDT will demand looking at several different types of validity during its development. Construct validity examines if there is a strong connection between the content and the test items. Content validity, also called face validity, inspects if the test items actually measures the concept from an expert's point-of-view. Communication validity checks if the test-taker understands the test items as the developers intended.

Water Cycle

> The global water cycle encompasses the flow of water, energy, and water-borne materials, and their interactions with organisms in the Earth system. Water's unique combination of physical and chemical properties, its co-existence as vapor, liquid, and solid within the temperature and pressure ranges found on Earth, and its role as an essential ingredient of the planet's sub-systems. As the principal atmospheric greenhouse gas, water vapor brings temperature into the range required for life on Earth. Powered by the sun, the water cycle couples the living and non-living components of Earth into an evolving system. Human activity is an integral and inseparable part of the water cycle, impacting and impacted by both the quantity and quality of water, (American Meteorological Society (AMS), 2001, p. 2).

Water Cycle Diagnostic Test (WCDT)

A three-tier, multiple-choice diagnostic instrument that has items specifically designed to identify alternative conceptions and misunderstandings of the water cycle.

Assumptions of the Study

The following assumptions will be made regarding this study:

1. The data for the dependent variable, the score on the WCDT, including student's confidence level, will be normally distributed.
2. There is homogeneity of the variance.
3. The higher the score on the WCDT, the better the students' conceptual understanding of the water cycle.
4. The participants will rate their overall confidence level of both tiers, and not just on one tier.
5. The participants who have a high score on the science section of the CBASE should score higher on the WCDT.

Limitations

The following limitations of the study are:

1. The most severe limitation of this study is the small sample size of PSTs who will participate in this study.
2. This study will involve only EPSTs and SPSTs who are enrolled during the fall semester of 2012 at a Midwest research university.
3. The alternative response choices on the WCDT are not the respondents' only potential alternative conceptions about the water cycle.
4. Selection of the alternative responses on the WCDT may have been influenced by students' non-scientific usage of scientific terms, and/or misunderstanding of scientific terms.

5. No attempt will be made to control the completion of the WDCT. This may influence the results of the study because some participants will take their time to complete the test while other participants may finish the instrument quickly.

Summary

This study will be an investigation of EPSTs' and SPSTs' conceptual knowledge of the water cycle. The investigation involves the development and validation of a reliable diagnostic three-tier test to measure PSTs' correct and alternative conceptions about the water cycle. This study will contain five chapters: the general introduction of the study is provided in Chapter One; a review of the related literature is provided in Chapter Two; a description of the procedures used in developing the instrument and for conducting the study is provided in Chapter Three; an analysis of the data will be provided in Chapter Four; and an overview of the study with a summary of the findings and discussion of future study will be provided in Chapter Five.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

The purpose of this chapter is to provide a review of the literature related to this study. This chapter begins with a description of the use of diagnostic tier tests (DTTs) to diagnose a student's conceptual understanding of a topic and alternative conceptions. Within that section, a table of current available DTTs is included. The second section is a review of the Certainty Response Index (CRI) that will be used to develop and analyze the third tier of the WCDT. The next two sections define the water cycle with its associated scientific components used in the development of the WCDT. The third section contains a review of past research that examined students' understanding and alternative conceptions about the water cycle. The final section will contain a review of the College Base Academic Subjects Examination (CBASE) that was used as a variable for comparison to the participants' scores on the WCDT.

Diagnostic Tier Tests

When examining Table 1, one can see a large void in the current available DTTs' assessed areas of science is the geosciences. At this time, there are no published or developed DTTs available in the geosciences, but there has been a recently developed DTT on the topic of environmental issues (Arslan, Cigdemoglu, & Moseley, 2012). The earliest two-tier DTT found in the archives was Novick and Nussbaum's (1981) Test about Particles in a Gas (TAP). This assessment was designed around students' misconceptions about the behavior of gases. It was an 8-question assessment that had two-tiers: the first-tier used a multiple choice format, which assesses student's conceptual knowledge of the topic, followed by an open-ended second-tier. The second-tier follow-

Table 1

Published and Available Science Diagnostic Assessments

Topic	Discipline	Authors
	Biology	
Photosynthesis and Respiration		Haslam & Treagust (1987)
Photosynthesis		Griffard & Wandersee (2001)
Diffusion and Osmosis Diagnostic Test (DODT)		Odom (1992); Odom & Barrow (1995); Odom & Barrow (2007) *
Breathing and Respiration		Mann & Treagust (1998)
Flowering Plant Growth and Development		Lin (2004)
Internal Transport in Plants and the Human Circulatory System		Wang (2004)
Natural Selection Instrument		Nehm & Reilly (2007)
Scientific Reasoning in Genetics		Tsui & Treagust (2010)
	Chemistry	
Test About Particles in a Gas (TAP)		Novick & Nussbaum (1981)
Covalent Bonding and Structure		Peterson, Treagust, & Garnett (1989)
Chemical Bonding		Tan & Treagust (1999)
Chemical Equilibrium		Tyson, Treagust, & Bucat (1999)
Test to Identify Students' Conceptualizations (TISC) / Chemical Equilibrium		Voska & Heikkinen (2000)
Qualitative Analysis (QADI)		Tan, Goh, Chia, & Treagust (2002)
Acids and Bases		Chiu (2001, 2002)
States of Matter		Chiu, Chiu, & Ho (2002)
Taiwanese Survey of Physics Concepts for Secondary Students		Tsai & Chou (2002)
Multiple Representation in Chemical Reactions (RSCRDI)		Chandrasegaran, Treagust, & Mocerino (2005)
Ionization Energies of Elements		Tan, Taber, Goh, and Chia (2005)
Chemical Reactions		Chandrasegaran, Treagust, & Mocerino (2007)
Particulate Nature of Matter/Chemical Bonding		Othman, Treagust, & Chandrasegaran (2008)
Burning		Chang, Lee, & Yen (2010)
Nature of Solutions and Solubility (NSS-DI)		Adadan & Savasci (2012)

(*Continued*)

Table 1

Continued

Physics	
Forces	Halloun & Hestenes (1985); Hestenes, Wells, & Schwackhamer (1992)
Light and Its Properties	Fetherstonaugh & Treagust (1992)
Force, Heat, Light, and Electricity	Franklin (1992)
Electric Current, Force, and Motion	Millar & Hames (2001)
Formation of Images by a Plane Mirror	Chen, Lin, & Lin (2002)
Electric Circuits	Tsai, Chen, Chou, & Lain (2007)
Optics	Chu, Treagust, & Chandrasegaran (2009)
Nature and Propagation of Waves **	Caleon & Subramaniam (2010a)
Properties and Propagation of Mechanical Waves (WADI) *	Caleon & Subramaniam (2010b)
Simple Electric Circuits (SECDT) *	Pesman & Eryilmaz (2010)
Atmosphere/Environmental Issues	
Atmosphere-related Environmental Problems (AREPDiT) *	Arslan, Cigdemoglu, & Moseley (2012)
Nature of Science	
Views of Nature of Science (VNOS)	Lederman, Abd-El Khalick, Bell, & Schwartz (2002)
Learning Cycle	
Learning Cycle Test (LTC)	Odom & Settlage (1996)
Understanding the Learning Cycle (ULC)	Marek, Maier, & McCann (2008)
Measurement	
Views About Scientific Measurement (VASM)	Buffler, Allie, Lubben, & Campbell (2001); Buffler, Lubben, & Ibrahim (2009)
Scientific Knowledge	
Conceptual Understanding in Science (Taiwan National Project)	Chiu, Guo, & Treagust (2007)

Note: *Three-tier test, **Four-tier test up, which explores a student's reason for selecting the first part, included students making drawings as part of the task to complete their answer. Since that time, two-tier tests usually use a multiple-choice format for both tiers, but there are some exceptions to the rule (e.g., Views on the Nature of Science [VNOS], Lederman et al., 2002). The VNOS uses an open-ended format for both tiers.

DTTs' first tier is usually structured and formatted in the same fashion as CIs (Figure 1), but with the inclusion of a second-tier, students are given a chance to select a reason as to why they selected the answer to the first-tier's question. DTTs differ from normal multiple-choice examinations used in the classroom because of the inclusion of distractors. Through extensive research, test developers find alternative conceptions that students may have, and then embed those misconceptions as distractors within the response selections. Therefore, identifying the level of a student's conceptual understanding and the possible reason as to why they selected an incorrect answer gives the evaluator a valuable insight into their current level of understanding the topic. The additional value of using a DTT is that students may "know" the correct answer for a test, but not have complete understanding as to why they selected the answer for the content portion.

Why not use an open-ended question format? Some researchers (Berlak, 1992) debate as to whether multiple-choice test formats actually tap into a person's higher-level thinking skills because using open-ended questions would allow students to write their

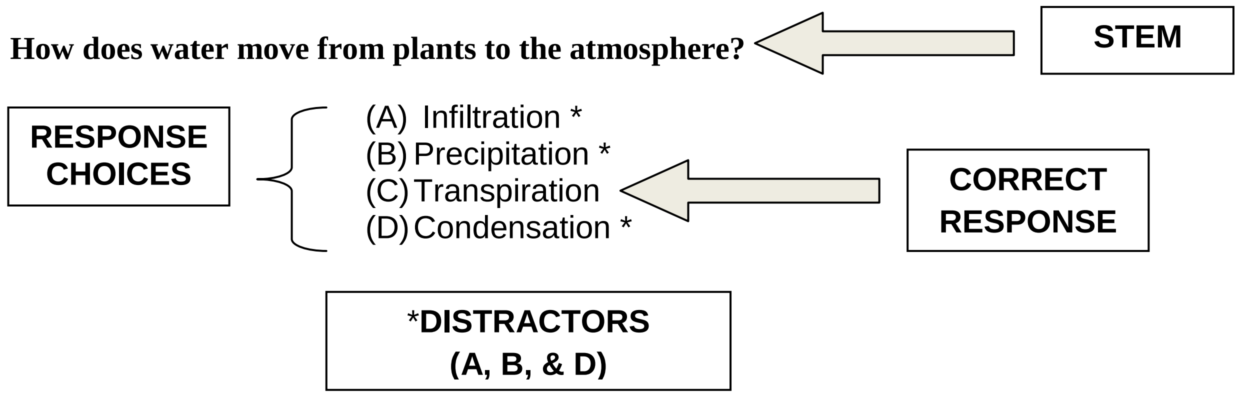

Figure 1. The structural format of a multiple-choice question found in the first tier of DDT.

complete response to the questions rather than to respond simply to a multiple-choice formatted item. However, this would also defeat one of the main purposes for using DTTs and CIs: saving time and money in assessing students, and in grading the test. Additionally, educators would only be able to administer a few questions if they used an open-ended format, and this would reduce a test's reliability (Hamilton, 1998; Klein et al., 1997).

Some researchers have noticed problems when administering two-tiered tests. Marek, Maier, and McCann (2008) noted that with two-tier assessments some students have other reasons than the ones found in the second tier for their selection in the first tier, and would rather have the chance to write out another reason for their selection. Grifford and Wandersee (2001) stated:

> … classroom teachers are far better poised to uncover their students' alternative conceptions simply by interacting with them. This instrument [two-tier test] is not necessary to uncover alternative conceptions in classrooms except in very formal classroom cultures or exceedingly large lecture classes that constrain these interactions, (p.1051).

Currently, there are very few three-tier tests developed (e.g., Caleon & Subramaniam, 2010a; Odom & Barrow, 2007; Pesman & Eryilmaz, 2010), but the third tier of a DTT has a multiple-choice Likkert scale ranking of confidence. Students rate the level of confidence for their selections found in the first two tiers. Confidence rankings such as these are very helpful to instructors because they allow them to see the strength of the student's conceptual understanding and to make adjustments to their instruction accordingly. If a student has a very strong confidence rating, but selects an alternative response on both tiers one and two of the DTT, then the teacher will probably have a harder time challenging that student's current scientific belief and content knowledge. If the confidence rating is low, the teacher might have an easier time altering those alternative conceptions and conceptual understanding of a topic. DTTs can pinpoint problem areas that concern student's content and alternative conceptions more quickly with the implementation of one assessment instead of two or more. Instructors can then develop classroom interventions that address the seriousness of students' alternative conceptions when found.

Certainty of Response Index (CRI)

Two-tier DTTs are not without their naysayers. Hasan, Bagayoko, and Kelly (1999) in discussing multiple-choice exams and DTTs, stated that "…the tests developed during such research, although refined, are cumbersome and not easily amenable to application in the classroom," (p. 294). The inclusion of the third tier with the CRI on a DTT allows instructors to determine the magnitude of the students' alternative conceptions and then to determine the type of instruction needed to modify those diagnosed problem areas. According to Caleon and Subramaniam (2010a), "The identification and investigation of ACs [alternative conceptions] is one of the most important tasks in educational research," (p. 940). The advantage of the additional third tier to the WCDT allows researchers to examine if the PSTs have an actual alternative conception or just has a lack of knowledge about the topic.

CRIs have been used in the social sciences for a while, but are relatively new in the development of DTTs since Odom and Barrow's (2007) revision of the Diffusion and Osmosis DTT (Odom, 1992; Odom & Barrow, 1995). Adding a confidence tier to the WCDT allows researchers to determine if a participant's answer is due to the lack of knowledge or if he/she has actually an alternative scientific conception about the water cycle. The WCDT will use a 4-point Likkert scale for participants' confidence. Participants will select will "guessing," "uncertain," "confident," or "very confident."

Water Cycle and Its' Components

There is a plethora of resources scientifically defining the water cycle. In *Science for All Americans* (Rutherford & Ahlgren, 1989), AAAS considers the water cycle as a necessary ingredient for Americans in achieving the goal of scientific literacy:

> The cycling of water in and out of the atmosphere plays an important part in determining climatic patterns-evaporating from the surface, rising and cooling, condensing into clouds and then into snow or rain, and falling again to the surface, where it collects in rivers, lakes, and porous layers of rock. There are also large areas on the earth's surface covered by thick ice (such as Antarctica), which interacts with the atmosphere and oceans in affecting worldwide variations in climate, (p. 43).

Although it did not provide a definitive definition of the water cycle, the AAAS provided a vital framework for educators, textbook writers, and publishers, etc. that helped in the development of a scientific definition of the water cycle. However, when reviewing a variety of publications and resources on this topic, the above guideline from the AAAS leaves the definition of the water cycle open to many interpretations.

In textbooks from kindergarten through introductory college courses in meteorology, the definition of the water cycle ranges from very simplistic to complex. At the elementary level, textbooks could make one wonder if the definition presented is age-appropriate or even if the definition will give a student the visual picture necessary for understanding. As for teachers, does the definition provided to them give enough content background to teach about the water cycle?

In the 1990's, the National Science Research Center (NSRC) developed an elementary science program called Science & Technology for Children (STC). Within that program, a series of modules were developed for classroom use. One module, *Weather* (NSRC, 1995), designed for students in grades kindergarten through second, defined the water cycle as follows:

> All water on earth is at one stage or another in a continuous cycle known as the water cycle. Water in the form of precipitation falls to the earth. There it soaks into the ground or collects in large bodies such as oceans, rivers, and lakes. The sun heats up the water on earth and causes it to turn to water vapor, a gas that rises. In other words, the water evaporates. As the water rises, it is cooled, or condensed, turning back into liquid water. Precipitation then falls to earth again, and the cycle continues, (p.109).

Clearly the above definition is intended as background knowledge for the elementary school teacher, and STC goes on to say, "Young students should not be expected to understand the water cycle" (p.109). Instead, this module wants the teacher to establish the foundation of the water cycle by having students look at water puddles outside on the playground or from pans with water placed around the classroom, and then have students make predictions about the vanishing water over a period of time. The goal of this lesson is more about students developing an understanding of the process of evaporation rather than the water cycle. In a later module developed for grades 3 and 4, NSRC (1997) continued to develop students‟ understanding of the water cycle in *Land and Water*.

In another elementary science curriculum program developed for students in grades 3 and 4, Full Option Science System's (FOSS) *Water Module* on water vapor states:

> The processes of evaporation and condensation continue endlessly in the water cycle. Energy from the sun causes water to evaporate from oceans, lakes, and plants. The relatively warm vapor rises and cools, condensing and falling back to earth. The water remains in or on the earth until it once again is warmed by the sun and vaporized, (1993, p.2).

This module mainly focuses upon the processes of evaporation and condensation with students looking at surface area temperature's effect on evaporation, as well as temperature's effect on condensation through several student investigations and a couple of demonstrations presented by the teacher.

The *Investigating Earth Systems: An Inquiry Earth Science Program* (American Geological Institute [AGI], 2002) was developed specifically for middle school/junior high earth science courses. This textbook series revolves around nine modules for teaching earth science. Two modules in this series particularly focus on the water cycle: *Climate and Weather* and *Water as a Resource*. In *Climate and Weather*, the water cycle is defined as a "model of circulation of water between the oceans, atmosphere, and the changes that occur within hours or days at a given location or region," (p. C91). The water cycle is described in a more detailed fashion in a section entitled "The Causes of Weather." Besides emphasizing evaporation and condensation, this section introduces several terms, including deposition, sublimation, transpiration, relative humidity, cloud development, and precipitation. Another module within this program, *Water as a*

Resource, provides students with another opportunity to further develop their content knowledge the water cycle.

According to most educational standards, both national and state, by the time a student reaches high school, the foundational basis for understanding the water cycle should have been well established and structured so that students can apply that knowledge to different set of scientific situations. For benchmarks pertaining to grades 9-12 under Structure of Matter from *Benchmarks for Science Literacy* (AAAS, 1993), "An enormous variety of biological, chemical, and physical phenomena can be explained by changes in the arrangement and motion of atoms and molecules" (p.80). Here the emphasis shifts and now the concentration is placed on how important the water cycle is when learning about the geochemical and biological cycles. High school science textbooks for Earth Science and Biology usually define the water cycle as the constant movement of water between the atmosphere and the Earth's surface (e.g., Hess, et al., 2008; Miller & Levin, 2006). Generally, high school students find a very limited amount of information in their Biology and Earth Science textbooks pertaining to the water cycle, and included with those limited explanations is usually a poorly constructed representation of the water cycle (Schaffer & Barrow, 2011).

College introductory meteorology textbooks refer to the water cycle as the hydrologic cycle. When defining the term, many textbook authors still use the same basic definition found in high school textbooks. Mainly, the authors focus on the movement of water vapor and its transition from the earth's surface to the atmosphere and back again through processes of evaporation, condensation, and precipitation (Lutgens & Tarbuck, 2010; Arhens, 2009).

The most complete definition of the water cycle found was developed by the American Meteorological Society (AMS) in 2001 as a theoretical framework for developing a course called, *Water in the Earth System* (WES). This professional development course was developed as part of their K-13 initiative to help classroom teachers gain content knowledge about the atmosphere, oceans, and hydrological sciences.

> The global water cycle encompasses the flow of water, energy, and water-borne materials, and their interactions with organisms in the Earth system. Water's unique combination of physical and chemical properties, its co-existence as vapor, liquid, and solid within the temperature and pressure ranges found on Earth, and its role as an essential ingredient of the planet's sub-systems. As the principal atmospheric greenhouse gas, water vapor brings temperature into the range required for life on Earth. Powered by the sun, the water cycle couples the living and non-living components of Earth into an evolving system. Human activity is an integral and inseparable part of the water cycle, impacting and impacted by both the quantity and quality of water, (p. 2).

Each definition of the water cycle was presented to reach its targeted audience with forethought and purpose by curriculum designers and textbook writers. The reason the definition developed by AMS is the best one today is because one would be able to gain a visual picture of the water cycle from its framework. Visually, one could see the sun as an important force energizing the water cycle, water existing in three phases, water vapor being the principal atmospheric greenhouse gas, and its importance for the existence of life here on the earth. With the other definitions, someone could only imagine water turning in circles, going up into the sky and coming back down again to the ground. This depiction of the water cycle tends to oversimplify the actual movement. Furthermore, those definitions did not consider the importance of water on earth. The question that needs to be addressed is this: what scientific processes of the water cycle truly need to be understood by students to achieve scientific literacy about this topic?

In a recent email from Howard Perlman, the coordinator for the *Water Science for Schools* website from the United States Geological Survey (USGS), states "…there are no set number of scientific categories (phenomena) for the water cycle," (Perlman, personal communication, March 28, 2011). At this time, the USGS identifies 16 components it thinks are necessary to discuss and understand when studying the water cycle. They are:

- Water storage in oceans
- Evaporation
- Sublimation
- Evapotranspiration
- Water in the atmosphere
- Condensation
- Precipitation
- Water storage in ice and snow
- Snowmelt runoff to streams
- Surface runoff
- Streamflow
- Freshwater storage
- Infiltration
- Groundwater storage
- Groundwater discharge
- Springs (Retrieved from http://ga.water.usgs.gov/edu/watercyclesummary.html

These are also visibly recognized in the USGS's representation of the water cycle found in Figure 2. At this time, the USGS's *Water Science for Schools* is the most widely recognized and used internet website in the world for information pertaining to the water cycle (Howard Perlman, personal communication, June 13, 2011). Its water cycle representation has been translated into 67 languages.

In another study completed by Schaffer and Barrow (2011), ten components were identified as essential when representing the water cycle in high school science textbooks. They were:

- Sun Depicted in Water Cycle Representation
- Evaporation Depicted Coming from both Land and from the Ocean
- Precipitation Shown Occurring both on the Land and the Ocean
- Condensation of Water Vapor
- Transpiration from Plants
- Infiltration/Seepage/Percolation of Water into Sub-surfaces
- Runoff of Water
- Groundwater
- Water Storage
- Life Process Depicting Animals and Plants Involvement (p. 6)

That study also developed a water cycle representation (Figure 3) that includes the ten components stated above. When comparing these two representations, the major difference between the USGS and the one developed by Schaffer and Barrow (2011) is that the USGS model breaks water storage into at least six components for their representation.

The National Oceanic and Atmospheric Administration's (NOAA) *Water Cycle* website is another popular internet website for learning about the water cycle. NOAA's representation (Figure 4) of the water cycle plays an integral role within its website. The website includes how representations of the water cycle can lead a person into thinking that water cycles goes through a specific path, but states "The actual path any given water molecule follows in a complete water cycle can be varied and complex and may not follow the exact path shown by a diagram" (NOAA, 2011, http://www.srh.noaa.gov/jetstream). The NOAA includes ten components in its representation, too. The representation is similar to the one developed by Schaffer and

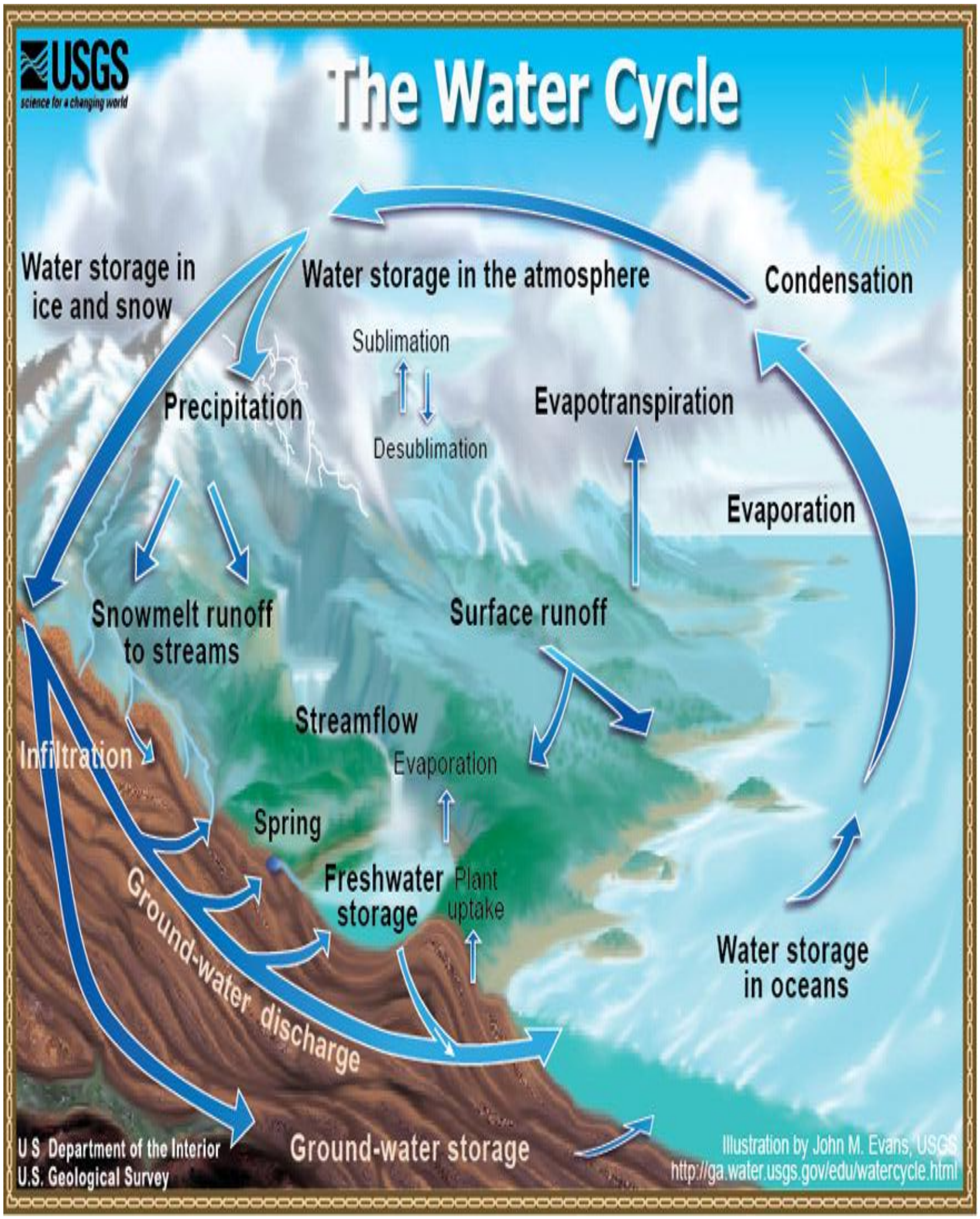

Figure 2. USGS Water Cycle Representation retrieved from:
http://ga.water.usgs.gov/edu/watercyclesummary.html

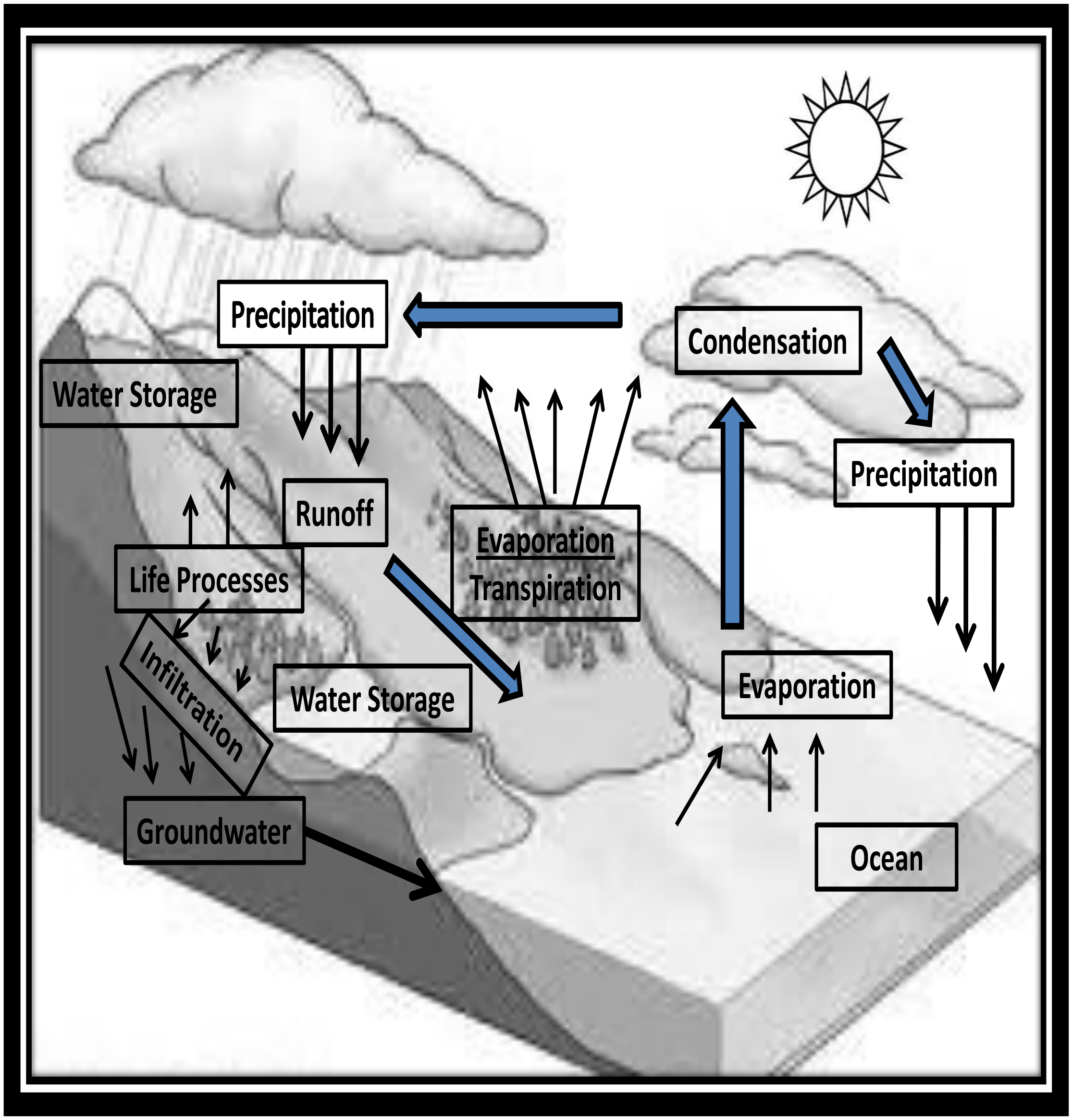

Figure 3. An ideal water cycle representation developed from the analysis of high school science textbooks, (Schaffer and Barrow, 2011, p. 7).

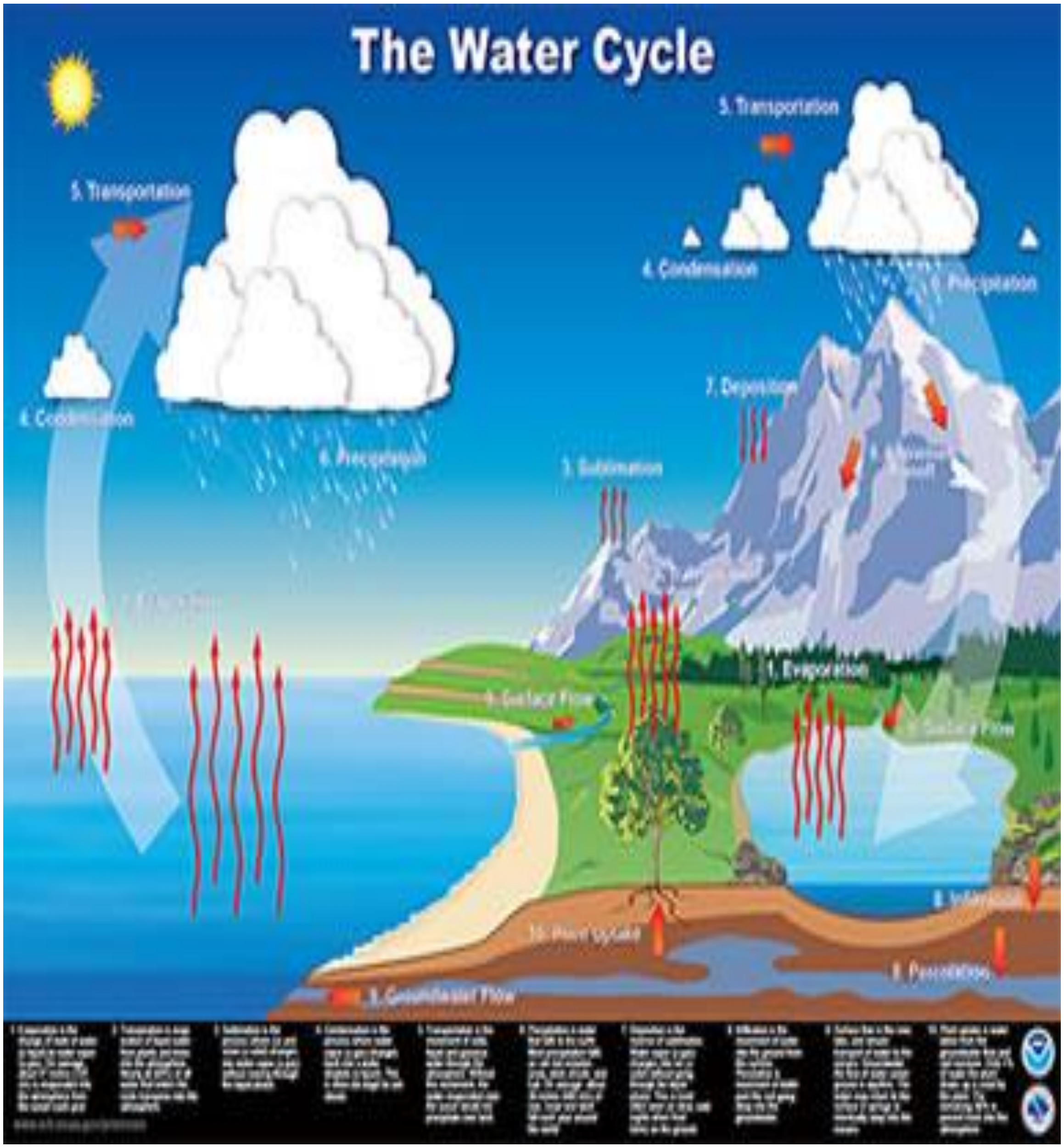

Figure 4. NOAA's water cycle representation found at:
http://www.srh.noaa.gov/jetstream/atmos/images/hydro.jpg

Barrow (2011), but included in its components are deposition and sublimation, which are not an integral part of the Schaffer and Barrow representation. In addition, NOAA uses the term “transportation” which is the movement of water (solid, liquid, and/or gas) in the atmosphere

Major Aspects of the Water Cycle

In a survey conducted by the USGS through its *Water Science in Schools* website, 34 % of the respondents believe that the oceans are the starting place for the beginning of the water cycle. Many of those individuals believe this because oceans cover 71% of the earth’s surface and contain 97% of the earth’s water (Harold Perlman, personal communication, March 28, 2011). In most textbooks researched, evaporation has been used as the starting point when teaching about the three main processes of the water cycle. This is because the other two processes (condensation and precipitation) cannot occur without the availability of water vapor in the atmosphere that is provided by evaporation.

Evaporation

Evaporation is “the process of converting a liquid to a gas (vapor)” (Lutgens & Tarbuck, 2010, p. 99). This physical process includes evaporation from surfaces of different bodies of water such as oceans, lakes, and rivers, but also from the soil and the surfaces of plants. While most of the yearly total for evaporation comes from the ocean surface (86 %), there are several other processes that contribute to water vapor in the air, including sublimation and transpiration (AMS, 2001). The process of evaporation requires absorbing latent heat from water or surrounding molecules. This absorption of latent heat by the atmosphere in essence causes a cooling effect. An example of this occurs during exercise when perspiration evaporates, making the exerciser cooler. The highest rates of evaporation are found in areas where more heating is readily available.

Sublimation and Transpiration

Besides the process of evaporation, sublimation and transpiration add water vapor to the atmosphere. Sublimation is the physical change of a solid directly into a gas without going through the liquid stage. One example of sublimation occurs in the winter as piles of snow disappear when the air temperatures are below freezing (AMS, 2001). Adding to the Earth's total amount of atmospheric water vapor is the living process of transpiration. This term means "the process whereby water that is taken up from the soil by plant roots eventually escapes as vapor through tiny pores (called stomata) on the surface of green leaves" (AMS, 2001, p. 5). An example of transpiration is that a grown oak tree will transpire more than 150,000 liters of water vapor each year, and a typical acre of growing corn each summer day can transpire over 13,000 liters (AMS, 2001). Another term found in resources when talking about evaporation, but in a limited in number, is "evapotranspiration." This term is the measurement of the amount of evaporation from the earth surface plus the transpiration from plants (AMS, 2001). This measurement usually contributes around 14 percent of the total water vapor found in the atmosphere (AMS, 2001).

Condensation

Condensation is "the changing of water vapor back into a liquid," (Ahrens, 2009, p. 90). Examples of condensation include clouds developing in the sky or water droplets forming on the outside of a glass of iced tea on a warm summer day. During condensation, water vapor molecules release latent heat to the environment, causing a warming effect in the atmosphere causing uplift which allows clouds to form. Deposition, like condensation, brings water vapor out of the atmosphere, but instead of changing into a liquid, it changes into a solid. Frost forming on the windshield of a car is an example of deposition. This term is now sometimes called "desublimation" by some resources (USGS, 2010).

Precipitation

Precipitation is "any form of water that falls from a cloud and reaches the ground" (Ahrens, 2009, p. 90). Precipitation can take many forms, including mist, rain, drizzle, snow, sleet, and hail. This third phenomenon is usually omitted by most K-12 science textbooks because it is felt that students have the proper conceptual knowledge due to visual examples and life experiences with precipitation.

Other Components of the Water Cycle

In addition, educators must also include how the sun energizes the water cycle by providing the necessary energy to start the evaporation process, and that without the sun, there would be no water cycle. This continual heating from the sun allows the water within the cycle to distribute heat from the equator to the poles like ocean currents. Another factor to consider in teaching the water cycle is gravity. Overlooked by many educators when teaching about the water cycle, is the force of gravity that brings all forms of water back to the Earth's surface and eventually brings water back to the oceans through processes of infiltration and surface runoff. Yet another concept for students to understand is the time it takes for the water cycle to complete its circulation. Some definitions of the water cycle indicated that the cycling of water may take hours or days to complete, but educators must also take into account water storage areas such as aquifers, glaciers, and the polar ice caps where water may not cycle back into the system for thousands of years. Using the time factor of hours and days for completing the water cycle may lead to some students' misconceptions.

Alternative Conceptions of the Water Cycle

Everyday, teachers are confronted with the reality that their students come into their classes with preconceived scientific notions about the world. An earlier study by Driver and Erickson (1993) concluded that teachers need to acknowledge that their students come into the classroom with both scientifically correct theories and incorrect ideas about how the natural world works. This means that teachers need to reorganize their instruction in such a way as to challenge those misconceptions. Ausubel (1968) mentioned that teachers should "Find out what the learner already knows and teach him accordingly," (p. 337).

Examining research studies that identify misconceptions in the geosciences, one finds very few when compared to other science disciplines (Lewis & Baker, 2010; Libarkin & Anderson, 2005). In the earliest study of diagnosing scientific misconceptions held by EPSTs, Rayla and Rayla (1938) gave 130 women a 240-item test covering these topics: agriculture, botany, zoology, forestry, chemistry, physics, astronomy, geology, geography, meteorology, physiology, and hygiene. Researchers felt the need to test over a wide range of science topics because elementary teachers need to have a broad fundamental understanding of many sciences that are addressed in elementary school. 109 misconceptions were identified in this study, and were sub-divided into six categories: "(1) the heavens; (2) earth, atmosphere, weather, and seasons; (3) chemical and physical facts and concepts; (4) biological facts and concepts; (5) foods and health;

and (6) superstitions" (p.245). When examining water cycle misconceptions, understanding of relative humidity was problematic because the participants thought that high relative humidity caused air to weigh more, and that lower relative humidity caused air to be less dense. In the category of covering superstitions, a large percentage of EPSTs thought that the weather is always good after rainbows appear, and that when the crescent moon points up, very little rain will occur.

Another study completed by Phillips (1991) examined 4-9th graders over a ten-year span, compiling data showing over fifty earth science misconceptions. He divided those misconceptions into the various spheres (i.e., hydrosphere, lithosphere, atmosphere, and biosphere). Common atmospheric misconceptions found for students in K-9th grade were:

- Rain comes from holes in clouds.
- Rain comes from clouds sweating.
- Rain occurs because we need it.
- Rain falls from funnels in the clouds.
- Rain occurs when clouds get scrambled and melt.
- Rain occurs when clouds are shaken.
- God and angels cause thunder and lightening
- Clouds move because we move.
- Clouds come from somewhere above the sky.
- Empty clouds are refilled by the sea.
- Clouds are formed by vapor from kettles.
- The Sun boils the sea to create water vapor.
- Clouds are made of cotton, wool, or smoke.
- Clouds are bags of water, (p. 21-22).

The significance of Phillips' research is that he documented that many of these misconceptions may continue through adulthood. The AAAS (2007) also acknowledged that many misconceptions may continue well into adulthood.

Another similar study was completed by Henriques (2000). In her study, Henriques reviewed research studies that focused upon children's misconceptions of the weather. In her literature review, she listed those research studies along with the misconceptions found by those researchers, and then listed possible reasons as to why students have them. Besides water cycle misconceptions, her study included phase changes of water, atmosphere and gases, seasons and heating of the earth, global warming and the greenhouse effect. Her overall perspective about the water cycle is that "younger children tend to view the water cycle by focusing on the properties of water. They see the water cycle primarily in terms of freezing and melting," (p. 3).

In a literature review covering K-12, Brody (1993) stated this about students' understanding about water: "Earth system knowledge related to water centers around the concept of the water cycle which is poorly understood by all students, …older students who have taken science courses have similar level of knowledge as elementary students and they possess more misconceptions about water and water resources" (p. 2). He also based his study on reviewing other studies that conducted research on student knowledge of water and water resources, which included knowledge of the water cycle.

Water Cycle

There are a limited number of research studies focusing upon student understanding of the water cycle (e.g., Bar, 1989; Ben-zvi-Assarf & Orion, 2005; Shepardson et al., 2009; Taiwo, 1999). Bar (1989) interviewed 300 Israeli children ranging from the ages five to fifteen about their understanding of the water cycle. From that data, she concluded that the water cycle can be introduced to students at the age of nine. This is when the concept of evaporation has been fully developed because that is the age when students finally have the ability to realize that both water and air are conserved. The process of condensation can be fully understood by the ages of eleven or twelve: "…

[this happens] when condensation can be distinguished from rainfall, and the mechanisms of rainfall could be explained by the idea of gravitation" (Bar, 1989, p. 499). By the time students reach the age of fifteen, Bar suggested that students take an advance class to further develop their content knowledge about the water cycle. Later studies by Bar and her colleagues (Bar & Galili, 1991; Bar & Travis, 1994) subsequently focused on the process of evaporation and the conceptual understanding of phase changes of matter.

In the Taiwo (1999) study, 888 Botswana elementary students were surveyed by using both an instrument and interviews. They concluded that Botswana children who lived in the urban areas of the country had a better understanding of the water cycle than those who lived in remote areas of the country. Taiwo suggested that students living in remote areas of the country had problems in their understanding due to a strong socio-cultural impact pertaining to tribal customs.

Ben-zvi-Assarf and Orion (2005) sampled 1000 junior high students from Israel in their study. They studied students' drawings of the water cycle, used a word association completion task, asked four questions pertaining to a variety of topics in the water cycle, and conducted 40 interviews. They concluded that students have many misconceptions about the water cycle, but particularly that students lacked an understanding of groundwater as part of the water cycle or even what groundwater is. Moreover, the studied population had "less than 10 %" of an understanding that the water cycle is an integral part of the biosphere and has an interaction with plants, animals, and humans (p. 368). Ben-zvi-Assarf and Orion went on to state that "…students perceive the "water cycle as a set of unrelated pieces of knowledge" (p.372). This means that when teaching each component of the water cycle in isolation, students tend to have an incomplete understanding of the cyclic nature of water cycle and thus develop misconceptions of the processes found in the water cycle, including that they occur in separation from one another.

Shepardson et al. (2009) researched over 1000 Midwest elementary and high school students in the United States. Students mostly thought of the water cycle as being just the processes of evaporation, condensation, and precipitation, and had an inadequate understanding on how water moves through the cycle. When Midwestern students drew the water cycle, they could only represent the water cycle by using a coastal or mountain feature in their diagram, and could not draw the water cycle as it occurred in the environment in which they lived. The representations which they drew were similar to the ones used in their science textbooks.

Prior to instruction about the water cycle, Cardak (2009) examined 156 Turkish university science education students' drawings of the water cycle followed up by interviews of 15 individuals. Five levels of conceptual understanding were developed as a rubric to evaluate the drawings: "Level 1; No drawing, Level 2: Non-representational drawings, Level 3: Drawings with misconceptions, Level 4: Partial drawings, and Level 5: Comprehensive representation drawings" (p.867). Several misconceptions were identified from the students' drawings. The main alternative conception found was that students' water cycle drawings only included the processes of evaporation and condensation. In the interviews, students were more explicit in their explanations, and researchers identified 15 misconceptions about the water cycle:

- Amount of water vapor in the air always remains unchanged
- Water amount in the biosphere differs according to climatic conditions
- The process of evaporation of water from the earth is the only determined by the sun

- Soil water only exists in regions with great rain area
- Starting point of the water cycle is seas and end point is uncertain
- Water amount in biosphere is gradually declining due to the melting of the glaciers
- Living things cannot exploit waters in seas and oceans since they are salty
- Water amount in biosphere is gradually declining due to global warming
- Underground water cannot be drunk since they are polluted, they can only be drunk after being purified
- Rain falls when clouds evaporate
- Water cycle includes the process of evaporation of water on the earth to the atmosphere and its return to the earth from the atmosphere by condensing
- Water cycle includes freezing and melting processes of water
- Water only evaporates from seas and oceans
- Water cycle is only composed of rain and snow
- Rain falls when clouds are completely filled up with water, (p. 869).

Morrell and Schepia (2009) also examined 78 EPSTs' drawings of the water cycle. As a pre-test, students were given a blank sheet of paper to either draw or write a description of the water cycle. After completing the task, students were asked to share their drawings and/or description with their classmates. After this task, students completed Project WET's (1995) activity, *The Incredible Journey*. Students were once again given their pre-test sheet, and then asked to redraw or describe the water cycle. Three months later, at the end of the semester, students were asked to duplicate the original task. Researchers found that these PSTs had the same alternative conceptions about the water cycle that have been previously noted in studies conducted on elementary and middle school students. Additionally, researchers concluded that using interventions such as the conceptual change teaching model and *The Incredible Journey* (Project WET Curriculum and Activity Guide, 1995) improved students' conceptual understanding of the water cycle, but that their drawings were still incomplete several months later when retested after the interventions were used in class. Nevertheless, some improvement was noted in their drawings. Morrell and Schepia went on to state: "They [PSTs] are wellversed in the atmospheric side of the cycle, but do not view the systemic components of the water cycle that includes the geosphere and biosphere" (p. 9).

When examining previous studies conducted on students' understanding of the water cycle, there was one (Morrell and Schepia, 2009) that had investigated PSTs' conceptual understanding of the water cycle. In that study, researchers only examined PSTs' representations of the water cycle, and gave only generalizations concerning the PSTs lack of knowledge, and did not provide a list of potential alternative conceptions the PSTs might have had about the water cycle. In the other studies (Bar, 1989; Ben-zvi-Assarf & Orion, 2005; Cardak, 2009; Shepardson et al., 2009; Taiwo, 1999), none focused on PSTs nor did the researchers use a diagnostic instrument to examine students' alternative conceptions like the one used in this study.

College Base Academic Subjects Examination (CBASE)

This mandated host state examination is taken after PST's first or second year of undergraduate studies depending on the university or college that the undergraduate is attending for their degree. A criterion-referenced multiple-choice examination, CBASE assesses the subjects of English, mathematics, science, social studies, and writing. Although the written portion of the CBASE contains some multiple-choice questions as well as having students write an essay. Scores range from 40 to 560 points for each subject area with the state setting a cut-score of 235 or higher for passing for each section. The scores are also reported descriptively as scoring high, medium, and low to the students (Assessment Resource Center, 2011).

This study used the CBASE score as one of its independent variables in its analysis. This is to examine if there is a relationship between pre-service teachers' score on the WCDT and the CBASE. The advantage of using PSTs' scores on the CBASE is that this diagnostic instrument that has been used on both the EPSTs and SPSTs prior the administration of the WCDT, and CBASE has tested the PSTs' knowledge of common scientific concepts. At this time, there are currently no research studies that have focused mainly upon the science section of the CBASE, but there have been some studies that examined performance of undergraduates on the CBASE (Cole, Bergin, & Whittaker, 2008; Cole & Osterlind, 2008; Flowers et al., 2001; Thorndike & Andrieu-Parker, 1992).

In Flowers et al (2001), 19,461 undergrads' CBASE science scores were examined from 56 4-year universities and colleges located in 13 states. Results of the study showed that after the first two years of attending college, both men and women had no significant change in their science knowledge when compared to those who were seniors that took the exam. Thorndike and Andrieu-Parker (1992) performed a two-year longitudinal study of 135 undergraduates using the CBASE as a pre-test and posttest to check reliability. Their study determined that the CBASE was a "high quality instrument with good test-retest reliability, but it adds little to information about entering students that is available from other sources," (p.1). Cole, Bergin, and Whittaker (2008) and Cole and Osterlind (2008) dealt with CBASE scores from the perspective of motivation. If the CBASE was considered "high stakes" for the person taking the assessment, then that individual was more motivated to perform well on the CBASE than those undergrads who perceived the CBASE as "low stakes."

Summary

The lack of research about the water cycle, especially on PSTs, presents a strong justification for further research into this area of geoscience. Therefore, this research study is designed to develop and validate a diagnostic three-tier test to identify alternative conceptions about the water cycle. The three-tier test is important because it will allow educators to detect efficiently and economically the alternative conceptions their PSTs have about the water cycle before entering a permanent position in teaching.

In this review of literature, it was concluded that DTTs are an efficient way to diagnose conceptual understanding and students' alternative conceptions. The definition of the water cycle varies depending upon the objective of researchers, authors, and/or agencies. Required components/phenomena of the water cycle also vary in the development of educational materials and how individual researchers perceived assessing the water cycle. Alternative scientific conceptions are present in all age groups of students, and in adults, too. Even after explicit instruction to teach individuals about the water cycle, alternative conceptions about the water cycle concepts can still exist. CBASE is can be used as an independent variable for comparison with the WCDT because of its associated science component.

CHAPTER THREE

METHODOLOGY

This chapter includes three major sections. The first section describes the theoretical framework used in the development and validation of the WCDT, and the statistical procedures to be used for determining reliability. The second section includes the research questions along with the null hypotheses statements, and a description of the survey included with the WCDT. The third section examines the refinement process used in the third stage in which the number of items on the WCDT was reduced through item analysis

Procedures for Developing and Validating the Water Cycle Diagnostic Test

This section summarizes the theoretical framework that was used in the development and validation processes of the WCDT. The framework was developed by Treagust (1986 1988, and 1995) and was originally based upon the learning theory of constructivism (David Treagust, personal communication, September 5, 2012). Since that time, many researchers have advocated the use of this particular strategy in the development and validation of DTTs (e.g., Lin, 2004; Odom, 1992; Pesman & Eryilmaz, 2010; Tsai & Chou, 2002). Treagust (1995) states that there are three main stages in developing a DTT:

1. "Defining the content
2. Obtaining information about students' conceptions
3. Developing a diagnostic instrument" (p.330).

For this study, a model of the theoretical framework (Figure 5) shows the step-by-step procedures that were used during its development and validation. Validating the WCDT

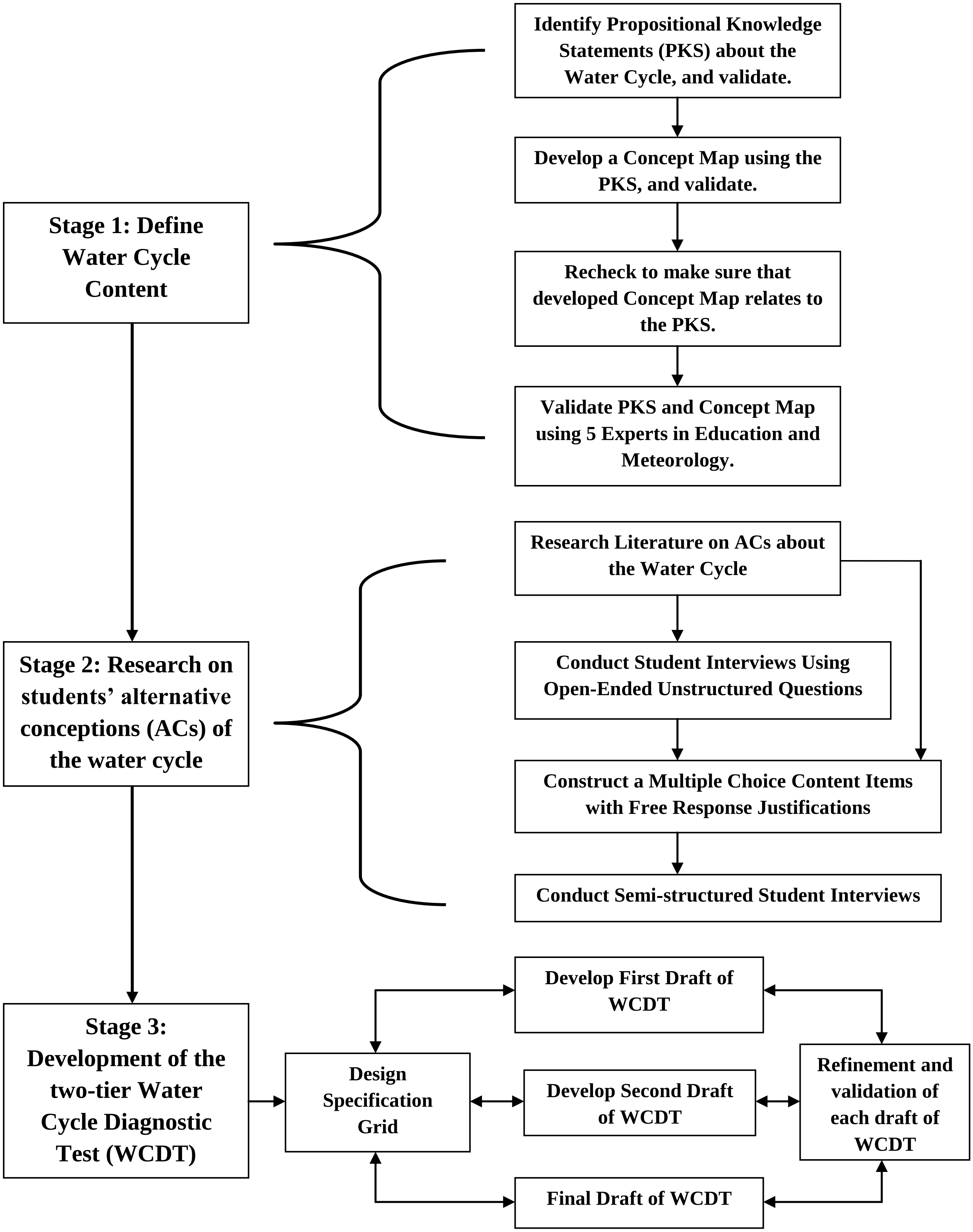

Figure 5. Structural Development Model for the Water Cycle Diagnostic Test (WCDT) based on Treagust (1986, 1988, and 1995)

used the following types of validity: construct, content, also called face validity, as well communication.

Stage One: Define Water Cycle Content

In Stage One, Defining the Content, a researcher needs to identify the propositional knowledge statements (PKSs). These PKSs (Table 2) establish the knowledge an individual needs to have for a complete conceptual understanding or for obtaining scientific literacy about a topic (e.g., Transpiration is a living process in which plants give water vapor back to the atmosphere). Ruiz-Primo (2000) states, “Propositional knowledge is knowing that something is so” (p. 30). The 47 PKSs were derived from the several college textbooks (Aguado and Burt, 2004; Arhens, 2009; Lutgens and Tarbuck, 2010), and from the American Meteorological Society’s *The Global Water Cycle* (2001).

After the completion and validation of the PKSs by three experts in the field of meteorology, a concept map (Figure 6) was crafted to connect all the PKSs, and to make sure that all parts of the concept were fully integrated into the development of the WCDT. Rather than using concept maps as a formative assessment, the concept map was used as an organization tool to represent the relationship between the PKSs. To ensure the content validity of PKSs and the concept map, five specialists in the fields of education and meteorology were sent both the PKSs and the concept map. Four of the experts are current professors of meteorology at major universities in the United States. The other expert was a weather educator from the American Meteorological Society (AMS) who has over twenty years of teaching experience with various AMS teacher

Table 2

PKSs Required for the Conceptual Understanding of the Water Cycle

Number	PKSs
1.	The sun provides almost all the energy to drive the water cycle on earth.
2.	Besides solar energy, gravitational forces of the earth also help with the movement of water through the water cycle.
3.	The water cycle goes through a variety of processes in order to complete its cycle.
4.	The water cycle has no starting or ending point.
5.	Water can change states of matter (water, ice, and water vapor) at various points within the water cycle.
6.	Temperature affects the process in which water goes from one state to another.
7.	Over seventy percent of the water on earth is contained in the global ocean.
8.	The total volume of water on earth is basically constant.
9.	The water cycle is basically a closed system, but minute traces of water could enter the earth's system from meteorites and comet debris.
10.	Most fresh water on earth is found in the polar ice caps and glaciers.
11.	Evaporation is the physical process by which water is transformed to water vapor when heat is absorbed.
12.	Water vapor is an invisible substance.
13.	Latent heat in the atmosphere is used during the evaporation process causing a cooling effect in the surrounding environment.
14.	Evaporation takes place at the surface of water.
15.	Additional heating of the earth's surface will increase the evaporation of water.
16.	Warm, dry air holds more water vapor than cold, moist air.
17.	Most of the water vapor in the atmosphere comes from the global ocean.
18.	Condensation is the physical process by which water vapor is transformed back into water when heat is absorbed.
19.	Latent heat in the atmosphere is released during the condensation process causing a warming effect in the surrounding environment.
20.	Clouds, fog, and dew are formed from the process of condensation.
21.	Clouds, fog, and dew are made up of water droplets and/or ice crystals, but not water vapor.
22.	Clouds are necessary for precipitation to occur, but it doesn't mean it will precipitate when clouds form.
23.	Clouds need condensation nuclei and water vapor to form.
24.	Precipitation is a physical process by which any solid or liquid form of water falls from clouds and reaches the surface of the earth.
25.	Precipitation only occurs when water particles are heavy enough to fall from clouds.
26.	Dew forms when air cools below its' dew point, and water vapor in the air condenses on surfaces as water droplets

(*Continued*)

Table 2

Continued

Number	PKSs
27.	Precipitation comes in many forms: Liquid precipitation includes mist, drizzle and rain; frozen precipitation includes snow pellets, snow grains, ice crystals, ice pellets, sleet, and hail, and freezing precipitation includes freezing drizzle and freezing rain.
28.	When air contains as much water vapor as it can hold at a certain temperature, the air is said to be saturated.
29.	Sublimation is the physical process by which ice and snow can directly change into water vapor when atmospheric temperatures are below 0° C/32°F.
30.	Frost and rime are formed from the process of deposition when air temperatures are at or below0° C/32°F.
31.	Frost is not frozen dew.
32.	Deposition is the physical process by which water vapor can directly change into ice without changing into water first.
33.	Transpiration is a living process by which water in plants is transported through leaf pores and changed into water vapor before being emitted into the environment.
34.	The greenhouse effect occurs when gases in the atmosphere are able to absorb infrared radiation from the earth, and reflect re-radiated back to the earth's surface.
35.	Water vapor is the major greenhouse gas in the atmosphere.
36.	Global warming will likely cause an acceleration of the water cycle.
37.	Humid air is less dense than drier air.
38.	Runoff of precipitation is dependent upon rainfall intensity, vegetation, topography, and physical properties of the land surface.
39.	Some of the precipitated water will infiltrate into the soil, and then percolate through the sub-soils to the water table.
40.	Water table flows into sub-surface groundwater that eventually flows into streams, rivers, lakes, and the oceans.
41.	Melting of glaciers and polar ice caps will add additional water to the global ocean.
42.	Melting of ice bergs will not add additional water to the global ocean because they are already included in the ocean's total volume.
43.	Raindrops are not teardrop-shaped.
44.	Falling raindrops flatten due to an increase in air pressure.
45.	Clouds are named mainly for their form and height of development.
46.	Basic cloud types include cirrus, cumulus, and stratus.
47.	Water sources for evaporation include oceans, rivers, streams, puddles, land surfaces, glaciers, polar ice caps, ice sheets, and plants.

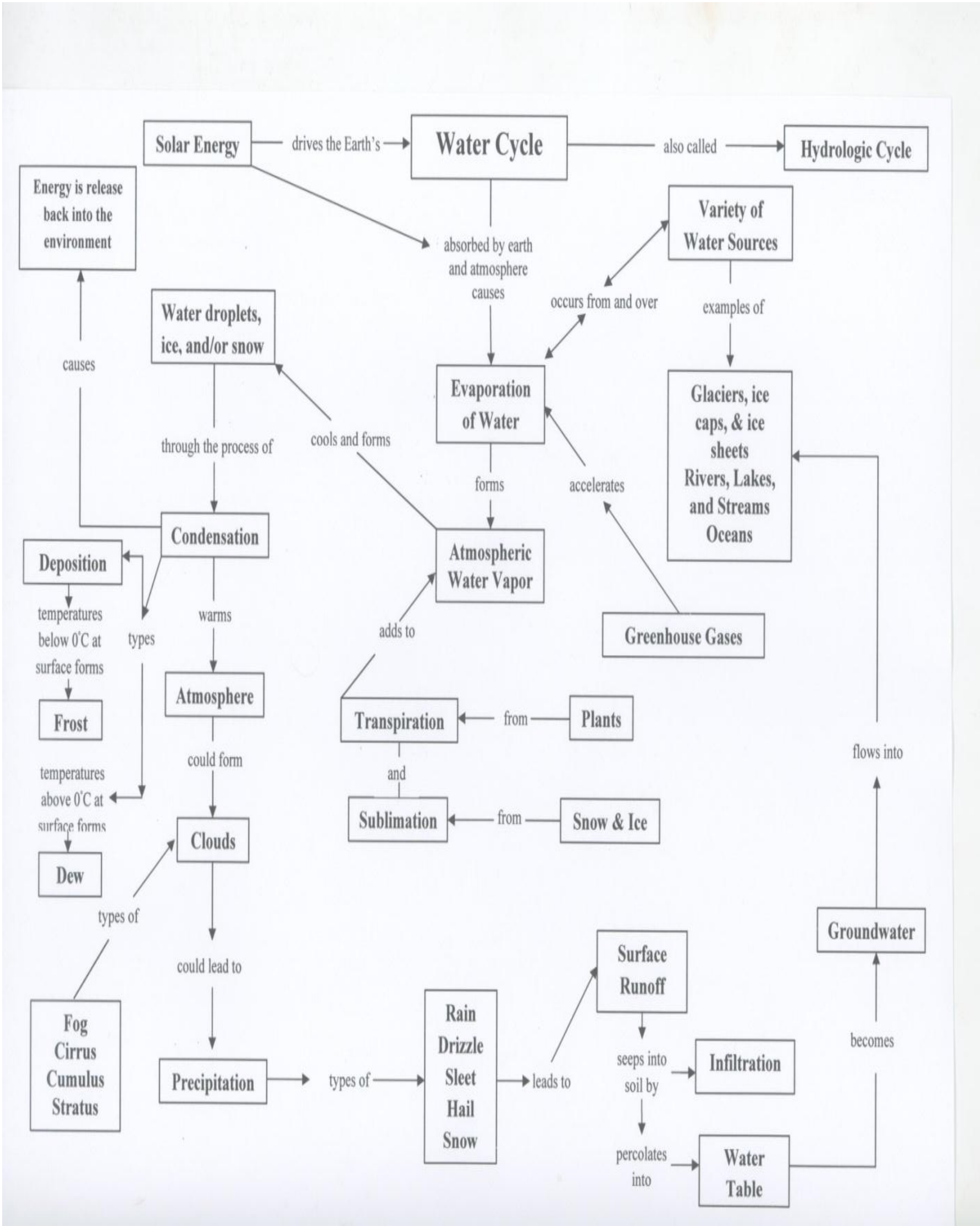

Figure 6. Concept map developed for the WCDT

education programs. The experts' review provided a reliability check to determine if the content was internally consistent with both the PKSs and the concept map.

Stage Two: Literature Review of Students' Alternative Conceptions

Stage two of developing the WCDT was obtaining information on students' alternative conceptions about the water cycle. Several top educational databases (e.g., Academic Search Premier, ERIC, Education Full Text, and Google Scholar) were used to retrieve articles for this literature review, as well as Duit's (2009) literature review on students and teachers' conceptions in science. The review of literature was used to check if any previous research studies identified problems that students might have in learning this concept and/or related processes of the water cycle. Treagust (1995) mentions that a literature review allows one "to build up a base of information for developing multiple choice items based on students' conceptions" (p.334). Several studies related to the water cycle were identified and read thoroughly (e.g., Bar, 1989; Russell, Harlen, & Watt, 1989; Bar & Travis, 1994; Bar & Galili, 1991; Taiwo, 1999; Ben-zvi-Assarf & Orion, 2005; Cardak, 2009; Shepardson et al., 2009). Possible alternative conceptions of the water cycle were noted for use during the construction of the WCDT pilot test.

During the review of literature for the WCDT, unstructured interviews were conducted with PSTs that had recently completed instruction concerning their knowledge on the water cycle. These PSTs were enrolled in Elementary Science Methods during the fall semester of 2011. Prior to that instruction, PSTs were first asked to create their own representation of the water cycle. After examining the students' drawings, the researcher interviewed six PSTs about their drawings and understanding of the water cycle. Examples of questions asked were: "What do you think the water cycle is?"; "What force(s) do you think drives the water cycle?" and "Explain how the mirror gets coated with water while you are taking a shower." While these interviews were going on, probing questions were asked to have the PSTs elaborate upon their answers. The researcher took field notes of the students' answers and then collected the drawings as artifacts with the participants' permission. At the end of instruction, the researcher asked the PSTs to complete another drawing of the water cycle and to write a reflection on how their drawings changed and why. To finish the second step, a pilot two-tier test was administered to the PSTs that included 34 multiple-choice questions with an open-ended question for the second tier so the PSTs could write a reason as to why they selected a particular answer on the content tier. This particular pilot was completed by 51 students from two different sections of Elementary Science Methods in the fall of 2011.The information provided by this pilot test was essential because it helped establish distractors needed in the development of response selections for both the first and second tiers in the next piloted version of the WCDT.

Refinement of the original pilot test continued with a second piloting of the WCDT that included 20 in-service secondary science teachers and community college geology instructors during the summer of 2012. The second piloting of the WCDT had multiple choice selections for both the first and second tiers. The in-service teachers also wrote comments that aided both in improving the content and communication validity of the WCDT. From this piloted test, two questions were eliminated, reducing the number of questions from 34 to 32 due to ambiguity.

Stage Three: Developing the Diagnostic Instrument

The third and final stage starts with designing a specification grid (Table 3) which allowed the WCDT developer to align the PKSs, concept map, and the developed assessment questions in order to make sure that all three essential content portions of the

Table 3

Specification Grid of the PKSs Matched with Items on the WCDT's Pilot Test

Question	PKS(s)
1	33
2	18, 19
3	1
4	11, 13
5	11, 17
6	7
7	7
8	10
9	8
10	1, 2
11	6, 28
12	14, 15
13	18, 19, 20, 21
14	12, 18, 19
15	29
16	18, 23
17	34, 35
18	30, 31
19	35
20	41, 42
21	5
22	45, 46
23	36
24	6, 11, 18
25	6, 11, 18
26	3, 4, 9
27	5, 22
28	16, 37
29	43, 44
30	45, 46
31	3, 4
32	38, 39

WCDT still had content validity. Treagust (1988; 1995) suggests doing several drafts before finalizing your DTT. In order to do this, the developer must refine and validate each time as one proceeds to the finalizing the instrument.

Certainty of Response Index (CRI)

Most DTTs are two-tier instruments. Developing a three-tiered assessment requires the implementation of a confidence tier along with the content and reason tiers. The WCDT used a 4-point Likkert scale for its confidence tier. Hasan, Bagayoko, and Kelly (1999) state “The CRI provides a measure of the degree of certainty with which a student answers each question” (p. 295). The WCDT will have a CRI that scores an individual’s confidence (1 to 4) varying from “Guessing,” “Uncertain,” “Confident,” or “Very Confident.” Scoring of the CRI will utilize the following matrix (Table 4) for categorizing individual and group scores. As part of the continual refinement process, eight participants will be selected for interviews. Each participant will be randomly selected by their WCDT score and overall confidence ranking. The goal is to interview four individuals who recorded a high CRI and four participants who rated their confidence level as low according the developed CRI matrix for the study.

Table 4

CRI Matrix for the WCDT

	Low CRI (< or = 2.0)	High CRI (> 2.0)
Correct Answer	Correct answer and low CRI Lack of Knowledge (lucky guess)	Correct answer and high CRI Knowledge of correct concepts
Wrong Answer	Wrong answer and low CRI Lack of Knowledge	Wrong answer and high CRI Alternative Conceptions

Modification of the Matrix Used for Odom and Barrow’s Three-Tier DODT, 2007

Reliability

In addition to being valid, assessment instruments must be reliable. Reliability of an evaluation tool is usually an estimated score, attained through the use of pre- and posttest scores or by calculating an assessment's internal consistency. Cronbach's alpha will be used to measure the internal consistency of each item on the WCDT

The input that each item has on the total score of the WCDT was determined by calculating the discrimination and difficulty indexes. Discrimination index will use a point-biserial correlation (r_{pbis}) that evaluates the discriminatory power of each item. The minimum value established for this study is 0.20. The difficulty index is a measurement of the proportion of the participants who answer an item correctly. The goal is to have a wide range of difficulty for items of the WCDT, but still have an overall average of 13.0 using the statistical index, Delta (Δ).

WCDT Survey

After completion of the WCDT, participants were asked the following demographic questions:

1. When was the last time you studied the water cycle?
2. Have you completed an atmospheric science/meteorology class as an undergraduate?
3. When was the last time you had an Earth Science class?
4. How often do you use the following media sources for obtaining news about the weather?
5. Which of the following severe weather events have you experienced?
6. What is gender?

The survey (Appendix C) was given additional information to the researcher in order to find if there is a relationship between the questions and the participant's score on the WCDT.

Research Questions and Hypotheses

The following research questions were developed to analysis PSTs' conceptual understanding of the water cycle.

1. How do EPSTs' and SPSTs' conceptual understanding compare concerning the water cycle?

   H_{O1}: There is no statistically significant difference between EPSTs' and SPSTs' scores on the WCDT regarding their conceptual understanding of the water cycle.

2. How do EPSTs' and SPSTs' conceptual understanding and confidence compare regarding the water cycle?

   H_{O2}: There is no statistically significant difference between EPSTs' and SPSTs' scores on the WCDT and their confidence regarding their conceptual understanding of the water cycle.

3. What is the relationship between EPSTs' and SPSTs' scores on the WCDT and their science scores' from the CBASE?

   H_{O3}: There is no statistically significant correlation between EPSTs' scores from the WCDT and their science scores on the *CBASE*.

   H_{O4}: There is no statistically significant correlation between SPSTs' scores from the WCDT and their science scores on the *CBASE*.

4. What is the relationship between the conceptual understanding of the water cycle held by those ESPTs and SPSTs who studied the water cycle as undergraduates and by those PSTs who last studied the water cycle during their K-12 education?

   $H_{O5:}$ There is no statistically significant correlation between EPSTs' and SPSTs' scores from the WCDT and when they last studied the water cycle.

   H_{O6}: There is no statistically significant correlation between the WCDT scores of EPSTs and SPSTs who studied the water cycle as undergraduates and those PSTs who last studied the water cycle on the K-12 level.

5. What is the relationship between the conceptual understanding of the water cycle held by those EPSTs and SPSTs who studied Earth Science as undergraduates and by those PSTs who last studied Earth Science during their K – 12 education?

   $H_{O7:}$ There is no statistically significant correlation between EPSTs' and SPSTs' scores from the WCDT and when those PSTs were last studied Earth Science.

6. What is the relationship between the conceptual understanding of the water cycle held by those EPSTs and SPSTs who have a higher interest in listening to and/or viewing weather-related media and by those PSTs who have a lower interest?

   H_{O8}: There is no statistically significant correlation between the WCDT scores of EPSTs' and SPSTs' who have a higher interest in listening and/or viewing weather-related media than those PSTs who have a lower interest in weather-related media.

7. What is the relationship between the conceptual understanding of the water cycle held by those EPSTs and SPSTs who have experienced severe weather events and those PSTs who have not experienced severe weather events?

H_{O9}: There is no statistically significant correlation between the WCDT scores of EPSTs' and SPSTs' that have experienced severe weather events than those pre-service teachers that have not experienced severe weather events.

8. What are the common alternative conceptions about the water cycle held by EPSTs and SPSTs?

Population

After introducing the study and obtaining signed permission letters (Appendix A) from the participants, the WCDT, along with the demographic survey, was administered to 77 PSTs enrolled in either an elementary or a secondary science method course taught during the fall of 2012. The sample consisted of 37 PSTS enrolled in two sections of LTC 4280, Teaching Science in the Elementary School. The other 40 PSTs were enrolled in two sections of LTC 4340/4631, Secondary and Middle School Science Methods I. Table 5 shows a breakdown by educational emphasis and gender of the PSTs involved in this study. 48.1 % of the participants were EPSTs, and 51.9 % were SPSTs, respectively. Only 23.4 % of the participants were male.

Prior to the administration of the WCDT, no formal instruction was given to the PSTs about the water cycle by course instructors or by the researcher. After the assessment, the EPSTs were given an opportunity to ask questions about the water cycle, and information about instructional resources and materials about the water cycle that the PSTs could use in the future was given to the participants. After the completion of the WCDT, SPSTs examined the water cycle with an introduction about the current drought situation in the United States and its relationship to global climate change.

Table 5

Number and Percent of PSTs that completed the WCDT by Teaching Emphasis and Gender

Educational Emphasis						
	Elementary n = 37		Secondary Science n = 40		Total n = 77	
Gender	n	%	n	%	n	%
Male	4	10.8	14	35.0	18	23.4
Female	33	89.2	26	65.0	59	76.6
Total	37	48.1	40	51.9	77	100.0

No time limit was placed upon the PSTs to complete both the WCDT and the demographic survey, but the researcher did note the time it took for participants to complete both parts, and whether any questions were asked by participants that would aid in the clarification of any test item. EPSTs took between 35 to 55 minutes to complete the WCDT and survey, and the SPSTs finished in 25 to 45 minutes. It was noted that the SPSTs felt that the WCDT was too long, and several of the participants mentioned that they would have liked the test broken into two sessions to allow for more thorough "thinking." EPSTs did not comment on the length or if they needed more time to complete the WCDT.

After completion of the WCDT and demographic survey, participants' answers on the WCDT and demographic survey were transcribed onto an Excel spreadsheet. Those answers were coded with no identifying markers to an individual's scores. After the data were transferred, an independent examiner checked 35 of the 77 answer sheets (45. 5 %) making sure that all answers were correctly recorded to the spreadsheet. The independent examiner found no errors in the transcription of the data from the PSTs' answer sheets to the Excel spreadsheet. Therefore, the inter-rater reliability was 100 %.

Preliminary Item Analysis

The first two tiers, content and reason, of each question on the WCDT were coded either as a “1” or a “0,” with “1” for a correct answer and a “0” an incorrect answer. After the first and second tiers were coded, a participant was given a final score for each question. In order to achieve correctness for a question, a participant must have achieved a “1” for both the content and reason tiers. If a participant received a “0” in either of those two tiers, then his or her answer was deemed incorrect.

After completion of coding for correctness, a variety of item analyses (Table 6) were performed for each question using SPSS 20.0. This item analysis was part of the revision process that was needed in order to refine the WCDT into a final version necessary for analysis. Several statistical tests were used to make this revision: Discrimination, Difficulty, Bias, Factor Analysis, and Reliability.

Item Discrimination

The item discrimination (Table 6) for the WCDT was determined by the point-biserial correlation coefficient. Point-biserial (r_{pbis}) is an item-level statistic that indicates the correlation between test-takers’ scores on a particular item (e.g., 0s or 1s on an item) and the corresponding total scores. The point-biserial correlation shows how well an item differentiates between high and low ability test takers. The larger the correlation, the greater the discriminatory power of that item. A positive value indicates that an item favors those participants who scored correctly on an item, and a negative value points to an item that discriminates towards the group of individuals who incorrectly answered the item. The range seen in the data analysis was from -0.063 (question 28) to 0.491 (question 14). An average point-biserial value of 0.20 has been established for this study.

Table 6

Discrimination, Difficulty, and Mean for Item Analysis on the WCDT

	Item Analysis		
Item	Discrimination r_{pbis}	Difficulty Δ	Mean M
1	0.364	15.260	0.286
2	0.420	12.540	0.545
3	0.205	10.420	0.740
4	0.376	15.420	0.273
5	0.086	15.260	0.286
6	0.333	8.240	0.883
7	0.172	8.240	0.883
8	0.297	13.720	0.429
9	0.467	13.460	0.455
10	0.145	10.420	0.740
11	0.212	13.200	0.481
12	0.222	8.950	0.844
13	0.116	18.680	0.078
14	0.491	10.420	0.740
15	0.183	20.750	0.026
16	0.337	15.420	0.273
17	0.235	16.440	0.195
18	0.243	19.500	0.052
19	0.341	17.760	0.117
20	0.099	17.270	0.143
21	0.223	19.500	0.052
22	0.167	14.820	0.325
23	0.063	12.540	0.545
24	0.289	16.440	0.195
25	0.126	18.040	0.104
26	0.129	21.850	0.013
27	0.322	17.270	0.143
28	-0.063	21.850	0.013
29	0.231	15.910	0.234
30	0.215	14.680	0.338
31	0.247	10.580	0.727
32	0.082	13.200	0.481

Item Difficulty

The item difficulty (Table 6) for the WCDT is characterized by a statistical index called delta (Δ). Delta has been defined as 13 + 4z, where z is the normal deviate corresponding to proportion correct. Delta values ordinarily range from 6.0 for a very easy item (i.e., approximately 95% of test takers select the correct answer) to 20 for a very hard item (i.e., approximately 5% of test takers select the correct answer) with a mean of 13.0 (50% correct). The range in which the WCDT fell was from 8.240 (items 6 and 7) to 21.850 (items 26 and 28). The Δ mean for the WCDT was 14. 94. This is higher than the difficulty wanted for the WCDT. Ideally, the goal was to have a wide range of item difficulty on the WCDT varying from easy to hard. This would make an average delta (Δ) of 13.0 as the overall goal for the WCDT (Holland and Thayer, 1985).

Item Bias

Differential functioning of items between EPSTs and SPSTs needed to be tested due to their different educational programs. We examined differential item functioning (DIF) using logistic regression procedures described in Swaninathan and Rogers (1990) as follows:

> Uniform DIF exists when there is no interaction between ability level and group membership. That is, the probability of answering the item correctly is greater for one group than the other uniformly over all levels of ability. Nonuniform DIF exists when there is interaction between ability level and group membership: that is, the difference in the probabilities of a correct answer for the two groups is not the same at all ability levels (p. 361).

In order to set-up these analyses, three hypothetical statements (see below) were developed. The first hypothesis represents No DIF; there is no statistically significant difference between the abilities of EPSTs and SPSTs, and the test items on the WCDT. In this case, the only significant predictor as to whether or not a teacher got the item correct is total score on the test. Second, we tested uniform DIF; to see if there is a statistically significant difference between in item difficulty between EPSTS and SPSTs, on WCDT items. We tested uniform DIF by attempting to add the group variable (elementary vs. secondary) to the model. Third, we tested non-uniform DIF; to see if there is a statistically significant difference between groups that varies with ability level. We tested non-uniform DIF by attempting to add the group*score interaction to the model. Model equations were developed and written below:

No DIF: Logit (y) = $b_o + b_1$ score

Uniform DIF: Logit (y) = $b_o + b_1$ score + b_2 group

Non-uniform DIF: Logit (y) = $b_o + b_1$ score + b_2 group + b_3 score x group

We failed to reject the null hypothesis; there is no statistically significant difference in item difficulty between groups with the exception of Item 25, which was shown to be biased toward secondary pre-service teachers. Results of this analysis can be found in Appendix D.

Factor Analysis

Factor analysis was conducted to identify latent variables within the data set, but also aided with data reduction. This was necessary due to the total number of items (32) on the WCDT, and to locate items that were correlated to one another even though Tabachnick and Fidell (2001) cites Comrey and Lee's (1992) when providing advice regarding sample size for conducting factor analysis:

> 50 cases is very poor, 100 is poor, 200 is fair, 300 is good, 500 is very good, and 1000 or more is excellent. As a rule of thumb, a bare minimum of 10 observations per variable is necessary to avoid computational difficulties (p. 588).

With a sample size of 77 participants and the large number of test items, it was felt that this type of analysis was significantly purposeful.

Using SPSS 20.0, after many analyses with different types of extraction methods, it was determined that the Principal Components Analysis with a Promax rotation would be the most useful for this study instead of using the Varimax method because Promax rotation allowed for factors to be correlated to one another (IBM, 2011). In addition, Promax will be useful in the future if another study is conducted using the same original items on the WCDT with a larger sample size.

With 15 iterations made during analysis, it confirmed that the items on the WCDT could be factored into five components (Table 7). This allowed for the reduction of 17 items from the original 32 questions, and leaving 15 items for a revised version of the WCDT. After factoring was completed, the items with the highest correlations (r) within a factor were kept (Table 8), and then each factor was coded with a common theme according to the questions kept within that factor.

Reliability

Reliability for the WCDT was calculated using Cronbach's alpha. Cronbach's alpha measures the coefficient of the internal consistency of an assessment. The ideal level for test reliability is a Cronbach's alpha (α) $\geq$ 0.70 (Crocker and Algina, 2008), and this had been set as a goal for the WCDT, but is above the acceptable threshold of 0.50 for multiple-choice item instruments (Nunnally, 1978) The WCDT's α before factor analysis was 0.45, but after the factor analysis with the reduction of items, α went up to 0.62. This is below the threshold for the goal set for the study's test reliability, but

Table 7

Five-Factor Dimensional Analysis Correlation Matrix using Principal Component Analysis with Promax Rotation on the WCDT

	Correlation Matrix				
	Factor				
Item	1	2	3	4	5
18	0.818				
19	0.615				
21	0.737				
2		0.711			
6		0.717			
14		0.752			
27			0.649		
30			0.785		
10				0.472	
17				0.675	
20				0.668	
4					0.450
7					0.746
9					0.405
16					0.520

Table 8

Breakdown of the Five-Factor Dimensional Analysis with Component Name, Items Selected, and Correlation Mean

Factor	Component Name	Items Selected	Correlation (r)
1	Phase Change of Water	18, 19, 21	0.724
2	Condensation & Storage	2, 6, 14	0.727
3	Clouds	27, 30	0.717
4	Climate Change	10, 17, 20	0.550
5	Movement through the Water Cycle	4, 7, 9, 16	0.530

Cronbach and Shavelson (2004) noted that Cronbach's "views about the way coefficient alpha had evolved, doubting now that the coefficient was the best way of judging the reliability of an instrument to which it was applied" (p. 391). One of the problems illustrating the inefficiency of measuring the reliability of an assessment using

Cronbach's alpha occurs when the sample size is small, and then the ideal threshold for coefficient alpha will not be achieved. Charter (2003) noted that with low sample sizes the coefficient alphas can be inconsistent. Several other researchers (Kline, 1986; Nunnally and Bernstein, 1994; Segall, 1994; Yurdugul, 2008) suggested a minimum of 300 sample size. Using the factor analysis on the WCDT enabled this study to obtain its highest test reliability at this time. Table 9 shows the breakdown of α for the five components obtained through factor analysis.

Table 9

Test Reliability Using Cronbach's Alpha for the WCDT

Factor	Component Name	Number of Items	Cronbach's Alpha α
1	Phase Change of Water	3	0.642
2	Condensation & Storage	3	0.614
3	Clouds	2	0.487
4	Climate Change	3	0.520
5	Movement through the Water Cycle	4	0.533
			Overall - 0.620

Summary

This chapter contained detailed information about the processes involved in developing and validating the WCDT using the theoretical framework developed by Treagust (1986, 1988, and 1995) for DTTs. The three stages of development and validation include the PKs, concept map, and specification grid. In addition, this section includes a description of CRI used for the WCDT's third-tier, the demographic survey questions, and determining reliability for the WCDT. The second section includes the research questions and null hypotheses for this study. The third section describes the population that participated in the study along with the statistical data using item analysis to reduce the number of items on the WCDT from 32 to 15. These include: Item Discrimination, Item Difficulty, Item Bias, Factor Analysis, and Reliability.

CHAPTER FOUR

ANALYSIS OF DATA

This chapter has six major sections of data presentation and analysis. The first section presents the descriptive statistics from the demographic survey questions asked in conjunction with the WCDT. The second section contains the descriptive statistics of the WCDT. The third section presents a detailed analysis of the individual items on the WCDT, and the third-tier of PSTs' confidence. The fourth section examines results from interviewing PSTs after the administration of the WCDT. The fifth section presents the inferential statistical data from the item analysis, and testing the null hypotheses. The sixth section includes a summary of the null hypotheses along with a list of potential alternative conceptions uncovered during the statistical analysis of the items on the WCDT.

Demographic Survey

The following analyses are for the five demographic questions (Appendix C) to which the PSTs responded on the WCDT. The demographic questions inquired about the PSTs' past weather-related experiences that may or may not have a relationship to the PSTs' final score on the WCDT.

Water Cycle

Descriptive statistics (Table 10) representing when the PSTs last studied the water cycle in school shows that the majority of the PSTs last studied the water cycle while in junior high school. When the PSTs' answers for when they last studied the water cycle in school are broken down by frequency, the mode for the EPSTs (35.1 %) is "Middle

School,” and the mode for when the SPSTs (32.5 %) last studied the water cycle would be “College.” Overall, the PSTs predominately selected “Middle School” was at 28.6%.

Table 10

Frequency of PSTs' Responses by Teaching Emphasis for Last Time Studied the Water Cycle in School

	EPSTs		SPSTs		Total	
Grade Level	n	%	n	%	n	%
Elementary	9	24.3	2	5.0	11	14.3
Middle School	13	35.1	9	22.5	22	28.6
Junior High	7	18.9	5	12.5	12	15.6
High School	5	13.5	11	27.5	16	20.8
College	3	8.1	13	32.5	16	20.8

Atmospheric Science

Descriptive statistics in Table 11 list the frequency with which PSTs have completed a course in atmospheric science and/or meteorology as an undergraduate. Data by frequency shows that none (0.0 %) of the EPSTs completed an atmospheric science and/or meteorology course as an undergraduate, whereas 11 (27.5 %) of the SPSTs have previously completed a course in atmospheric science and/or meteorology; however, the mode for the majority of SPSTs indicates that they have not taken an undergraduate course in atmospheric science and/or meteorology. Overall, 14.3 % of the PSTs in this study have completed an atmospheric science and/or meteorology course.

Table 11

Frequency of PSTs' Responses by Teaching Emphasis for Completion of an Undergraduate Course in Atmospheric Science and/or Meteorology

Teaching Emphasis	n	%
Elementary Education	0	0.0
Secondary Science	11	27.5
Total for PSTs	11	14.3

Earth Science

Descriptive statistics in Table 12 in regards to when the PSTs were last enrolled in an Earth Science course show that most of the PSTs were last enrolled in an Earth Science course during junior high school. Data analysis by frequency and percent of PSTs shows that the mode for the EPSTs (35.1 %) is "Middle School," but another large percentage (32.4 %) completed an Earth Science course while in high school. The mode for the SPSTs is both "High School" and "College" with 32.5 % each of that participants' grouping. This represents 65.0 %. Overall, "High School" was selected by most of the PSTs at 32.5 %.

Table 12

Frequency of PSTs' Responses by Teaching Emphasis for the Last Time Enrolled in an Earth Science Course in School

	EPSTs		SPSTs		Total	
Grade Level	n	%	n	%	n	%
Elementary	2	5.4	0	0.0	2	2.6
Middle School	13	35.1	7	17.5	20	26.0
Junior High	5	13.5	6	15.0	11	14.3
High School	12	32.4	13	32.5	25	32.5
College	5	13.5	13	32.5	18	23.4

Media Usage

Descriptive statistics (Table 13) for the fourth survey question focuses upon the PSTs' use of media sources to obtain weather-related information. Table 14 breaks down the PSTs' answers by frequency and percentage. "Rarely" do PSTs (37.7 %) use local radio with 43.2 % of the EPSTs and 32.5 % of the SPSTs agreeing with this selection. For local television, PSTs (39.0 %) selected "Sometimes" with 40.5 % of the EPSTs and 37.5 % of the SPSTs, respectively. The PSTs responded "Rarely" in regards to watching *The Weather Channel* (TWC) on television at 42.9%, while 50.6 % of the PSTs go to the web version of TWC, “Often.” The majority (79.2 %) of the PSTs’ responded with “Never” in regards to using a NOAA Weather Radio for receiving weather information. PSTs’ selected “Often” for when they used a phone app for receiving weather information at 58.4 %. EPSTs’ selected “Often” for use of the internet for weather announcements and information at 67.6 % and SPSTs at 57.5 %. Overall, PSTs’ made this selection at 62.3 %. At 36.4 %, the PSTs “Rarely” use other social media sources.

Severe Weather Experiences

Descriptive statistics (Table 15) for the fifth survey question asked the PSTs whether or not they have experienced different severe weather phenomena. Further breakdown of data (Table 16) shows that tornadoes were experienced by a majority of the PSTs (61.0 %), with the EPSTs at 51.4 % and SPSTs at 70.0 %. Most PSTs (93.5 %) have not experienced a hurricane. EPSTs experienced flooding at 48.6 % whereas 57.5 % of the SPSTs experienced flooding. Overall, 53.2 % of the PSTs had experienced flooding. Hail over two inches in diameter was experienced by 64.9 % of the PSTs. Snow avalanches (97.4 %), lightning (85.7 %), and mudslides (96.1 %) have rarely been experienced by any of the PSTs in the study. Drought greater than three months has been experienced by 58.4 % of PSTs with 62.2 % of EPSTs and 55.0 % of the SPSTs, respectively. Overall, hail was the most experienced of all of the severe weather phenomena (M = 0.65, SD = 0.48).

Inter-correlations with the WCDT

When examining the inter-correlations (Table 17) of the demographic questions with the PSTs’ WCDT scores, data shows that taking an atmospheric science and/or

Table 13

Descriptive Statistics of PSTs' Responses by Teaching Emphasis for Usage of Media to Obtain Weather-Related Information

			Descriptive Statistics			
Media	Level	n	Mean	*SD*	Median	Mode
Local Radio						
	EPSTs	37	1.49	0.87	1	1
	SPSTs	40	1.13	1.07	1	0
	Total	77	1.30	0.99	1	1
Local TV						
	EPSTs	37	2.08	0.92	2	2
	SPSTs	40	1.83	0.96	2	2
	Total	77	1.95	0.94	2	2
TWC-TV						
	EPSTs	37	1.32	1.00	1	1
	SPSTs	40	1.33	1.00	1	1
	Total	77	1.32	0.99	1	1
TWC-Web						
	EPSTs	37	2.11	1.02	2	3
	SPSTs	40	2.03	1.21	3	3
	Total	77	2.06	1.12	2	3
NOAA Weather Radio						
	EPSTs	37	0.24	0.55	0	0
	SPSTs	40	0.30	0.61	0	0
	Total	77	0.27	0.58	0	0

(*Continued*)

Table 13

Continued

		Descriptive Statistics				
Media	Level	n	Mean	*SD*	Median	Mode
Cell Phone-App						
	EPSTs	37	2.35	1.09	3	3
	SPSTs	40	1.98	1.21	2.5	3
	Total	77	2.16	1.16	3	3
Internet						
	EPSTs	37	2.59	0.64	3	3
	SPSTs	40	2.40	0.81	3	3
	Total	77	2.49	0.74	3	3
Social Media						
	EPSTs	37	1.65	1.03	2	1
	SPSTs	40	1.48	1.01	1	1
	Total	77	1.56	1.02	1	1

Table 14

Frequency of PSTs' Responses by Teaching Emphasis for Usage of Media to Obtain Weather-Related Information

	Never				Rarely				Sometimes				Often			
	EPSTs		SPSTs		EPSTs		SPSTs		EPSTs		SPSTs		EPSTs		SPSTs	
Media Source	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Local Radio	4	10.8	14	35.0	16	43.2	13	32.5	12	32.4	7	17.5	5	13.5	6	15.0
Local TV	3	8.1	4	10.0	5	13.5	10	25.0	15	40.5	15	37.5	14	37.8	11	27.5
TWC-TV	7	18.9	9	22.5	18	48.6	15	37.5	5	13.5	10	25.0	7	18.9	6	15.0
TWC-Web	4	10.8	7	17.5	5	13.5	4	10.0	11	29.7	7	17.5	17	45.9	22	55.0
NOAA Weather Radio	30	81.1	31	77.5	5	13.5	6	15.0	2	5.4	3	7.5	0	0.0	0	0.0
Cell Phone-App	5	13.5	8	20.0	2	5.4	5	12.5	5	13.5	7	17.5	25	67.6	20	50.0
Internet	0	0.0	1	2.5	3	8.1	5	12.5	9	24.3	11	27.5	25	67.6	23	57.5
Social Media	5	13.5	7	17.5	13	35.1	15	37.5	9	24.3	10	25.0	10	27.0	8	20.0

Table 15

Descriptive Statistics of PSTs' Responses by Teaching Emphasis for Experiencing Severe Weather Phenomena

		Descriptive Statistics		
Weather Phenomena	Level	n	Mean	*SD*
Tornado				
	EPSTs	37	0.51	0.51
	SPSTs	40	0.70	0.46
	Total	77	0.61	0.49
Hurricane				
	EPSTs	37	0.08	0.28
	SPSTs	40	0.05	0.22
	Total	77	0.06	0.25
Flooding				
	EPSTs	37	0.49	0.51
	SPSTs	40	0.58	0.50
	Total	77	0.53	0.50
Hail (> 2 in.)				
	EPSTs	37	0.65	0.48
	SPSTs	40	0.65	0.48
	Total	77	0.65	0.48
Blizzard				
	EPSTs	37	0.49	0.51
	SPSTs	40	0.55	0.50
	Total	77	0.52	0.50
Snow Avalanche				
	EPSTs	37	0.05	0.23
	SPSTs	40	0.00	0.00
	Total	77	0.03	0.16
Struck by Lightning				
	EPSTs	37	0.19	0.40
	SPSTs	40	0.10	0.30
	Total	77	0.14	0.35
Drought				
	EPSTs	37	0.38	0.49
	SPSTs	40	0.45	0.50
	Total	77	0.42	0.50

Table 16

Frequency of PSTs' Responses by Teaching Emphasis for Experiencing Severe Weather Phenomena

	EPSTs				SPSTs				Total			
	Yes		No		Yes		No		Yes		No	
Weather Phenomena	n	%	n	%	n	%	n	%	n	%	n	%
Tornado	19	51.4	18	48.6	28	70.0	12	30.0	47	61.0	30	39.0
Hurricane	3	8.1	34	91.9	2	5.0	38	95.0	5	6.5	72	93.5
Flooding	18	48.6	19	51.4	23	57.5	17	42.5	41	53.2	36	46.8
Hail (>2 in.)	24	64.9	13	35.1	26	65.0	14	35.0	50	64.9	27	35.1
Blizzard	18	48.6	19	51.4	22	55.0	18	45.0	40	51.9	37	48.1
Snow Avalanche	2	5.4	35	94.6	0	0.0	40	100.0	2	2.6	75	97.4
Struck By Lightning	7	18.9	30	81.1	4	10.0	36	90.0	11	14.3	66	85.7
Mudslides	1	2.7	36	97.3	2	5.0	38	95.0	3	3.9	74	96.1
Drought	14	37.8	23	62.2	18	45.0	22	55.0	32	41.6	45	58.4

Table 17

Inter-*correlations between Demographic Survey Questions* and *the PSTs' score* on the *WCDT*

Subscale	1	2	3	4	5	6
1. Studied Water Cycle	__	0.47*	0.43	0.11*	0.21	0.22
2. ATMS Undergraduate		__	0.27*	0.15*	0.02*	0.31
3. Studied Earth Science			__	0.07*	0.08	0.18
4. Media Usage				__	0.17*	-0.09
5. Weather Experiences					__	0.13
6. WCDT Score						__

*ρ < .01

meteorology course had a medium correlation, according Cohen's (1988) Guidelines, on the PSTs' WCDT score ($r = 0.31$, $\rho < .01$). In addition, when PSTs last studied the water cycle had slightly higher medium correlation with when the PSTs last studied Earth Science ($r = 0.47$, $\rho < .01$), and if the PSTs had completed an atmospheric science and/or meteorology course ($r = 0.43$, $\rho < .01$). The significance of the correlation values were calculated using the following non-directional hypothesis for Pearson Coefficient:

H_o: $\rho = 0$ $\quad$ H_1: $\rho \neq 0$ $\quad$ $\alpha = .01$ $df = 77$

$r_{critical} = \pm .2866$ $\quad$ If $[r_{observed}] \geq [r_{critical}]$ then Reject H_o

Descriptive Statistics for the WCDT

After the refinement of the WCDT instrument, descriptive statistics were calculated for the final version's 15 items. Table 18 summarizes the PSTs' total score on the WCDT. After revision, the reliability calculated by Cronbach's alpha

Table 18

Descriptive Statistics for the WCDT

Number of Items	15
Number of Participants	77
Mean/*SD*	5.83/2.15
Percent of Correct Scores	38.9
Minimum	2
Maximum	11
Cronbach's Alpha	0.62
Difficulty Indices (Δ)	
Mean/*SD*	14.44/3.76
n of items (range 8.0 – 12.0)	4
n of items (range 12.0 – 16.0)	5
n of items (range 16.0 – 20.0)	6
Point-biserial Correlation Coefficient (r_{pbis})	
Mean/*SD*	0.29/0.12
n of items (range 0.4 – 0.6)	3
n of items (range 0.2 – 0.4)	9
n of items (range < 0.2)	3

increased from 0.45 to 0.62, which is above the acceptable threshold of 0.50 set for multiple-choice item instruments (Nunally, 1978). The difficulty index (Δ) of items ranged from 8.24 to 19.5, providing a wide range of difficulty with an overall average of 14.44. Therefore, the WCDT is slightly more difficult than the average Δ of 13.00. The discrimination indices (r_{pbis}) ranged from 0.10 to 0.49 for the 15 items. The goal for the WCDT was to have all the items with discrimination indices greater than 0.20, only three items did not meet this criterion.

Table 19 summarizes the PSTs' means and standard deviations for the WCDT's first two tiers, the third-tier confidence ratings, and the CBASE scores. The PSTs have an overall mean of 5.83 (*SD* = 2.13) for the WCDT. This resulted in a total score of 38.9 % for the WCDT. Overall, the EPSTs (*M*= 5.03, *SD* = 2.09) for a score of 33.5 %, and for

Table 19

Mean and Standard Deviation of Scores on the WCDT, Third-Tier Confidence, and CBASE

	Teaching Emphasis	n	*M*	*SD*
WCDT	Elementary	37	5.03	2.09
	Secondary	40	6.58	1.90
	Total	77	5.83	2.13
Confidence Tier				
	Elementary	37	2.36	0.42
	Secondary	40	2.54	0.55
	Total	77	2.45	0.50
CBASE				
	Elementary	33	303.24	48.13
	Secondary	40	337.88	47.92
	Total	73	322.22	51.01

the SPSTs (*M* = 6.58, *SD* = 1.90) with a total score of 43.9 %. Overall, the WCDT's third tier confidence ratings shows that the PSTs have a mean of 2.45 (*SD* = 0.50) for the third tier. The EPSTs' confidence mean for the WCDT's third tier was 2.36 (*SD* = 0.42) and 2.54 (*SD* = 0.55) for SPSTs, respectively.

Additionally, the CBASE was used to examine if there is a relationship to the PSTs' scores on the WCDT. The total sample size was smaller (n = 73) than the one used to examine relationships within the WCDT (n = 77) due to participants either (1) being exempt from the CBASE, (2) not having completed the CBASE at the time of the recording of scores, or (3) not reporting scores because they had not yet passed all parts of the CBASE. Overall, the PSTs have a mean of 322.22 (*SD* = 51.01). The mean and standard deviation for the EPSTs' CBASE scores were (*M* = 303.24, *SD* = 48.13) and (*M* = 337.88, *SD* = 47.92) for the SPSTs' CBASE, respectively.

Analysis of Individual WCDT Items

Phase change of water

Item 1 (Table 20) assessed the PSTs' understanding of the process of deposition within the water cycle. Only 2.7 % of the EPSTs and 7.7 % of the SPSTs selected both the content and reason tiers correctly. This gave an average of 5.3 % for item 1. EPSTs (43.2 %) thought that "Condensation" was the answer to the content tier, whereas SPSTs' answers were evenly divided among all four selections provided in the content tier with the correct selection at 28.2 %. For the reason tier, the EPSTs (45.9 %) and the SPSTs (64.0 %) selected the same alternative response as their reason for the occurrence of frost; "Happens when water vapor changes into ice and the temperature below 32°F/0°C."

Item 2 (Table 21) assessed PSTs' understanding of greenhouse gases in the atmosphere. Only 5.4 % of the EPSTs and 17.5 % of the SPSTs selected the content and reason tiers correctly. This gave item two an overall mean of 11.7 %. Both EPSTs and SPSTs thought that "Carbon dioxide" was the answer to the content tier at 78.4 % and 60.0 %, respectively. For the reason tier, both the EPSTs (45.9 %) and SPSTs (27.5 %) selected the same alternative response; "Gained through the processes of excretion and respiration by animals," as the most common response.

Item 3 (Table 22) addressed latent heat used during the phase changes of water. None (0.0 %) of the EPSTs and only 10.0 % of the SPSTs selected both the content and reason tiers correctly. This gave an overall average of 5.2 %. EPSTs thought that "Convection" was the answer to the content tier at 40.5 %, whereas SPSTs responded to that selection at 50.0 %. For the reason tier, 67.5 % of the EPSTs and 52.5 % SPSTs

ITEM 1

On a beautiful morning in late November, you go outside and all of the windows on your car are covered with frost. Why did this frost form?

a. Condensation
b. Deposition [a]
c. Temperature change
d. Sublimation

The reason for your selection is because:

a. The air temperature falls below 32°F/0°C.
b. Happens when water vapor changes into ice and the temperature is below 32°F/0°C.
c. A direct change from a gas to a solid regardless of the temperature. [a]
d. Happens when water changes to ice near the earth's surface when the temperature is near or below 32°F/0°C.

Table 20

PSTs' Responses by Teaching Emphasis and Percent for Item 1

		Reason									
		a		b		c		d		Total	
Emphasis	Choice	n	%	n	%	n	%	n	%	n	%
Elementary	a	3	8.1	10	27.0	2	5.4	1	2.7	16	43.2
	b	2	5.4	3	8.1	1	2.7[a]	3	8.1	9	24.3
	c	3	8.1	3	8.1	1	2.7	1	2.7	8	21.6
	d	0	0.0	1	2.7	0	0.0	3	8.1	4	10.8
	Total	8	21.6	17	45.9	4	10.8	8	21.6		
Secondary	a	1	2.6	6	15.4	0	0.0	3	7.7	10	25.6
	b	0	0.0	7	17.9	3	7.7[a]	1	2.6	11	28.2
	c	0	0.0	5	12.8	0	0.0	4	10.3	9	23.1
	d	1	2.6	7	17.9	1	2.6	0	0.0	9	23.1
	Total	2	5.0	25	62.5	4	10.0	8	20.0		
Composite	a	4	5.3	16	21.1	2	2.6	4	5.3	26	34.2
	b	2	2.6	10	13.2	4	5.3[a]	4	5.3	20	26.3
	c	3	3.9	8	10.5	1	1.3	5	6.6	17	22.3
	d	1	1.3	8	10.5	1	1.3	3	3.9	13	17.1
	Total	10	13.0	42	54.5	8	10.4	16	20.8		

[a] correct choice and reason

ITEM 2

What is the most prevalent greenhouse gas found in the atmosphere?

a. Carbon dioxide
b. Methane
c. Water vapor [a]
d. All of the above have the same concentration in the atmosphere.

The reason for your selection is because:

a. Gained through the processes of excretion and respiration by animals.
b. Gained through the process of transpiration by plants.
c. Varies with the season and time of day.
d. Causes the greatest warming of the atmosphere by an atmospheric gas. [a]

Table 21

PSTs' Responses by Teaching Emphasis and Percent for Item2

		Reason									
		a		b		c		d		Total	
Emphasis	Choice	n	%	n	%	n	%	n	%	n	%
Elementary	a	13	35.1	7	18.9	0	0.0	9	24.3	29	78.4
	b	2	5.4	0	0.0	0	0.0	2	5.4	4	10.8
	c	0	0.0	0	0.0	0	0.0	2	5.4[a]	2	5.4
	d	2	5.4	0	0.0	0	0.0	0	0.0	2	5.4
	Total	17	45.9	7	18.9	0	0.0	13	35.1		
Secondary	a	9	22.5	2	5.0	1	2.5	12	30.0	24	60.0
	b	2	5.0	0	0.0	0	0.0	1	2.5	3	7.5
	c	0	0.0	3	7.5	1	2.5	7	17.5[a]	11	27.5
	d	0	0.0	2	5.0	0	0.0	0	0.0	2	5.0
	Total	11	27.5	7	17.5	2	5.0	20	50.0		
Composite	a	22	28.6	9	11.7	1	1.3	21	27.3	53	68.8
	b	4	5.2	0	0.0	0	0.0	3	3.9	7	9.1
	c	0	0.0	3	3.9	1	1.3	9	11.7[a]	13	16.9
	d	2	2.6	2	2.6	0	0.0	0	0.0	4	5.2
	Total	28	36.4	14	18.2	2	2.6	33	42.9		

[a] correct choice and reason

ITEM 3

Latent heating of the atmosphere refers to heat transferring through the process of:

a. Conduction
b. Convection
c. Radiation
d. Phase changes of water [a]

The reason for your selection is because:

a. Changing from a solid to liquid to a gas provides heating for the water cycle. [a]
b. The sun's energy provides heating for the atmosphere.
c. There is no transfer of energy when water molecules change to water vapor.
d. When water particles come into contact with one another and transfer energy.

Table 22

PSTs' Responses by Teaching Emphasis and Percent for Item 3

		Reason									
		a		b		c		d		Total	
Emphasis	Choice	n	%	n	%	n	%	n	%	n	%
Elementary	a	3	8.1	3	8.1	1	2.7	3	8.1	10	27.0
	b	3	8.1	12	32.4	0	0.0	0	0.0	15	40.5
	c	0	0.0	10	27.0	1	2.7	1	2.7	12	32.4
	d	0	0.0[a]	0	0.0	0	0.0	0	0.0	0	0.0
	Total	6	16.2	25	67.6	2	5.4	4	10.8		
Secondary	a	2	5.0	4	10.0	1	2.5	1	2.5	8	20.0
	b	4	10.0	10	25.0	3	7.5	3	7.5	20	50.0
	c	1	2.5	7	17.5	0	0.0	0	0.0	8	20.0
	d	4	10.0[a]*	0	0.0	0	0.0	0	0.0	4	10.0
	Total	11	27.5	21	52.5	4	10.0	4	10.0		
Composite	a	5	6.5	7	9.0	2	2.6	4	5.2	18	23.4
	b	7	9.0	22	28.6	3	3.9	3	3.9	35	45.5
	c	1	1.3	17	22.1	1	1.3	1	1.3	20	25.9
	d	4	5.2[a]	0	0.0	0	0.0	0	0.0	4	5.2
	Total	17	22.1	46	59.7	6	7.8	8	10.4		

[a] correct choice and reason, * $\rho < .05$, ** $\rho < .01$

selected the same common alternative response, “When the sun’s energy provides heating for the atmosphere.”

Condensation and Storage

Items 4, 5, and 6 are part of the second factor, condensation and storage. Item 4 (Table 23) assessed the PSTs’ understanding of the process of condensation within the water cycle and the conservation of matter. EPSTs and SPSTs selected both the content and reason tiers correctly at the fairly high rate of 64.9 % and 82.5 %, respectively. This gave an overall mean of 74.0 %. “From the beverage and ice condensing inside the can” was selected as an incorrect answer in the content tier by 21.6 % of the EPSTs, whereas 15.0 % of the SPSTs selected that answer. For the reason tier, 23.9 % of the EPSTs and only 12.5 % of the SPSTs selected the same incorrect alternative response, “The beverage warmed and caused water to condensate inside the can, and the extra water caused too much volume in the can and seeped out,” as the reason for the occurrence of the water on the outside of the glass.

Item 5 (Table 24) examines only the concept of condensation. EPSTs selected both the content and reason at 54.1 % and the SPSTs at 55. 0 %. This gave an overall mean of 54.5 %. Over 70 % of the PSTs selected the correct answer for the content tier, but for the reason tier, the selections were fairly evenly distributed depending on what the participant selected for the content tier. The EPSTs selected the alternative response, “Condensation is a cooling process like low humidity on a warm summer day,” at 16.2, and for 22.5 % of the SPTSs selected, “Condensation is a warming process like high humidity on a warm summer day” as their response for their reason tier.

ITEM 4

On a hot summer day, you get a cold beverage from the refrigerator. You put the can down on a table, and a little while later you return and notice a puddle of water has formed around the outside of the can. Where did this water come from?

a. From the ice melting inside the can.
b. From the beverage and ice melting from the can.
c. From the beverage and ice condensing inside the can.
d. From the air outside the beverage. [a]

The reason for your selection is because:

a. Warming of beverage caused the beverage to expand and spill out of the can.
b. Ice on the outside of the beverage melted and created the puddle.
c. The beverage warmed and caused water to condensate inside the can, and the extra water caused too much volume in the can and seeped out.
d. Water vapor from the atmosphere cooled and condensed when coming into contact with the cold beverage. [a]

Table 23

PSTs' Responses by Teaching Emphasis and Percent for Item 4

		Reason									
		a		b		c		d		Total	
Emphasis	Choice	n	%	n	%	n	%	n	%	n	%
Elementary	a	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	b	0	0.0	1	2.7	1	2.7	1	2.7	3	8.1
	c	1	2.7	0	0.0	5	18.5	2	5.4	8	21.6
	d	1	2.7	0	0.0	1	2.7	24	64.9[a]	26	70.3
	Total	2	5.4	1	2.7	7	18.9	27	72.9		
Secondary	a	0	0.0	1	2.5	0	0.0	0	0.0	1	2.5
	b	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	c	0	0.0	0	0.0	5	12.5	1	2.5	6	15.0
	d	0	0.0	0	0.0	0	0.0	33	82.5[a]	33	82.5
	Total	0	0.0	1	2.5	5	12.5	34	85.0		
Composite	a	0	0.0	1	1.3	0	0.0	0	0.0	1	1.3
	b	0	0.0	1	1.3	1	1.3	1	1.3	3	3.9
	c	1	1.3	0	0.0	10	13.0	3	3.9	14	18.2
	d	1	1.3	0	0.0	1	1.3	57	74.0[a]	59	76.6
	Total	2	2.6	2	2.6	12	15.6	61	79.2		

[a] correct choice and reason

ITEM 5

Condensation happens when water vapor rises into the atmosphere and:

a. Cools [a]
b. Warms

The reason for your selection is because:

a. Condensation is a cooling process like low humidity on a warm summer day.
b. Condensation is a warming process like high humidity on a warm summer day.
c. Water cools to its saturation point and condensation occurs. [a]
d. Water warms to its vaporization point and condensation occurs.

Table 24

PSTs' Responses by Teaching Emphasis and Percent for Item 5

		Reason									
		a		b		c		d		Total	
Emphasis	Choice	n	%	n	%	n	%	n	%	n	%
Elementary	a	6	16.2	1	2.7	20	54.1[a]	1	2.7	28	75.7
	b	0	0.0	4	10.8	1	2.7	4	10.8	9	24.3
	Total	6	16.2	5	13.5	21	56.8	5	13.5		
Secondary	a	3	7.5	2	5.0	22	55.0[a]	1	2.5	28	70.0
	b	0	0.0	7	17.5	0	0.0	5	12.5	12	30.0
	Total	3	7.5	9	22.5	22	55.0	6	15.0		
Composite	a	9	11.7	3	3.9	42	54.5[a]	2	2.6	56	72.7
	b	0	0.0	11	14.3	1	1.3	9	11.7	21	27.3
	Total	9	11.7	14	18.2	43	55.8	11	14.3		

[a] correct choice and reason

Item 6 (Table 25) asked participants about their understanding of the source for moisture in the atmosphere. EPSTs selected both the content and reason at 89.2 % and the SPSTs at 87.5 %. This gave an overall mean of 88.3 %.

Clouds

Items 7 and 8 are part of the third factor dealing with clouds. Item 7 (Table 26) assessed the participants' understanding of how clouds are named and formed. Only 21.6 % of the EPSTs and 46.2 % of the SPSTs selected both the content and reason tiers correctly. This gave an overall mean of 34.2 %. EPSTs selected the correct content answer at 75.7 %, but for the reason tier, they selected "Stratus clouds usually cause precipitation" at 27.0 %, and "When a cloud name starts with 'alto' it means low in atmosphere" at 32.4 %. SPSTs selected the correct content answer at 92.3 %, but also selected "When a cloud name starts with 'alto' it means low in atmosphere" by 28.2 % of participants for the reason tier.

Item 8 (Table 27) assessed the PSTs' understanding of the phase change of water in clouds. Only 8.1 % of the EPSTs and 20.0 % of the SPSTs selected both the content and reason tiers correctly. This gave an overall mean of 14.3 %. EPSTs selected the correct content answer at 54.1 %, but also selected "Water in clouds never freezes" at 45.9 %, whereas SPSTs selected the correct content answer at 52.5 % and "Water in clouds never freezes" at 42.5 %. For the reason tier, 70.2 % of the EPSTs and 65.0 % of the SPSTs selected the same alternative response as their reason for the changing of water to ice in clouds, "Water droplets cool while falling to earth, and change into ice."

ITEM 6

Which of the following is the major source of moisture that reaches or becomes part of Earth's atmosphere?

a. Lakes
b. Rivers
c. Polar caps
d. Oceans [a]

The reason for your selection is because:

a. When compared to other water sources, the oceans cover over 70% of the earth's surface. [a]
b. Lakes are shallower than oceans, and water can evaporate more quickly from their surfaces into the atmosphere.
c. The rapid movement of water in the world's river systems causes moisture to be transported from the earth's surface to the atmosphere at a greater rate than lakes and the oceans.
d. Polar ice caps and glaciers contain fresh water which is easily transferred to the earth's atmosphere.

Table 25

PSTs' Responses by Teaching Emphasis and Percent for Item 6

		Reason									
		a		b		c		d		Total	
Emphasis	Choice	n	%	n	%	n	%	n	%	n	%
Elementary	a	0	0.0	2	5.4	0	0.0	0	0.0	2	5.4
	b	0	0.0	0	0.0	0	0.0	2	5.4	2	5.4
	c	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	d	33	89.2[a]	0	0.0	0	0.0	0	0.0	33	89.2
	Total	33	89.2	2	5.4	0	0.0	2	5.4		
Secondary	a	0	0.0	2	5.0	0	0.0	0	0.0	2	5.0
	b	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	c	0	0.0	0	0.0	0	0.0	3	7.5	3	7.5
	d	35	87.5[a]	0	0.0	0	0.0	0	0.0	35	87.5
	Total	35	87.5	2	5.0	0	0.0	3	7.5		
Composite	a	0	0.0	4	5.2	0	0.0	0	0.0	4	5.2
	b	0	0.0	0	0.0	0	0.0	2	2.6	2	2.6
	c	0	0.0	0	0.0	0	0.0	3	3.9	3	3.9
	d	68	88.3[a]	0	0.0	0	0.0	0	0.0	68	88.3
	Total	68	88.3	4	5.2	0	0.0	5	6.5		

[a] correct choice and reason

ITEM 7

Basic cloud types are named upon:

a. Form.
b. Height.
c. Both form and height. [a]

The reason for your selection is because:

a. Cirrus clouds are wispy that form high in the atmosphere and are compose of ice crystals. [a]
b. When a cloud name starts with 'alto' it means low in atmosphere.
c. Cumulus clouds form horizontally to the earth's surface.
d. Stratus clouds usually cause precipitation.

Table 26

PSTs' Responses by Teaching Emphasis and Percent for Item 7

		Reason									
		a		b		c		d		Total	
Emphasis	Choice	n	%	n	%	n	%	n	%	n	%
Elementary n = 37	a	1	2.7	0	0.0	3	8.1	0	0.0	4	10.8
	b	2	5.4	3	8.1	0	0.0	0	0.0	5	13.5
	c	8	21.6[a]	9	24.3	1	2.7	10	27.0	28	75.7
	Total	11	29.7	12	32.4	4	10.8	10	27.0		
Secondary n = 39	a	1	2.6	1	2.6	0	0.0	0	0.0	2	5.0
	b	0	0.0	0	0.0	1	2.6	0	0.0	1	2.5
	c	18	46.2[a]*	10	25.6	3	7.7	5	12.8	36	92.3
	Total	19	48.7	11	28.2	4	10.3	5	12.8		
Composite n = 76	a	2	2.6	1	1.3	3	3.9	0	0.0	6	7.9
	b	2	2.6	3	3.9	1	1.3	0	0.0	6	7.9
	c	26	34.2[a]	19	25.0	4	5.3	15	19.7	64	84.2
	Total	30	39.5	23	30.3	8	10.5	15	19.7		

[a] correct choice and reason

ITEM 8

Water in clouds may change from liquid to solid:

a. Only at 32˚F/0˚C.
b. At 32˚F/0˚C and temperatures below 32˚F/0˚C. [a]
c. At temperatures above 32˚F/0˚C.
d. Water in clouds never freezes.

The reason for your selection is because:

a. Water vapor does not freeze in clouds.
b. Water droplets cool while falling to earth, and change into ice.
c. Clouds can have supercooled water in them. [a]
d. Water vapor goes directly to a solid without forming a liquid.

Table 27

PSTs' Responses by Teaching Emphasis and Percent for Item 8

		Reason									
		a		b		c		d		Total	
Emphasis	Choice	n	%	n	%	n	%	n	%	n	%
Elementary	a	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	b	0	0.0	16	43.2	3	8.1[a]	1	2.7	20	54.1
	c	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	d	7	18.9	10	27.0	0	0.0	0	0.0	17	45.9
	Total	7	18.9	26	70.3	3	8.1	1	2.7		
Secondary	a	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	b	1	2.5	11	27.5	8	20.0[a]	1	2.5	21	52.5
	c	0	0.0	1	2.5	1	2.5	0	0.0	2	5.0
	d	2	5.0	15	37.5	0	0.0	0	0.0	17	42.5
	Total	3	7.5	27	67.5	9	22.5	1	2.5		
Composite	a	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	b	1	1.3	27	35.1	11	14.3[a]	2	2.6	41	53.2
	c	0	0.0	1	1.3	1	1.3	0	0.0	2	2.6
	d	9	11.7	25	32.5	0	0.0	0	0.0	34	44.2
	Total	10	13.0	53	68.8	12	15.6	2	2.6		

[a] correct choice and reason

Climate Change

Factor 4 includes items 9, 10, and 11. Item 9 (Table 28) assessed the PSTs' understanding of the cause(s) of movement of water within the water cycle. EPSTs selected both the content and reason at 67.6 % and the secondary science pre-service teachers at 80.0 %. This gave an overall mean of 74.0 %.

Item 10 (Table 29) assessed the understanding of which atmospheric gas is the main cause of an increase in atmospheric heating by the greenhouse effect. EPSTs selected both the content and reason at 16.2 % and the SPSTs at 22.5 %. This gave an overall mean of 19.5 %. EPSTs selected the correct content answer of "Water Vapor" at 21.6 %, but selected an alternative answer of "Carbon Dioxide" at 59.5; whereas SPSTs' answers selected the correct content answer, "Water Vapor," at 30.0 % and "Carbon Dioxide" at 57.5 %. For the reason tier, 37.8 % of the EPSTs and 27.5 % SPSTs selected the same incorrect alternative response as their reason, "Increases in global population produce more of this gas." Overall, PSTs selected this alternative response for the reason tier at 32.5 %.

Item 11 (Table 30) assessed the understanding of the melting of sea ice and its effect on global sea levels. EPSTs selected both the content and reason at 10.8 % and the SPSTs at 17.5 %. This gave an overall mean of 14.3 %. Overall, 84.4 % of the participants selected the "Sea level to rise" for the content tier with EPSTs at 86.5 % and SPSTs at 82.5 %, respectively. For the reason tier, 86.5 % of the EPSTs and 80.0 % SPSTs selected the same incorrect alternative response as their reason, "The extra water produced due to the melting will cause sea level to rise and flood coastal areas." In total, participants selected this incorrect alternative response for the reason tier at 83.1 %.

ITEM 9

The flow of water in the water cycle is caused by:

a. The heat from the sun
b. The gravitational attraction of the earth
c. The gravitational attraction from the moon
d. Both a and b [a]

The reason for your selection is because:

a. Any movement on earth is controlled by its' own gravitational forces.
b. The energy of the sun causes water vapor to evaporate into the atmosphere, and earth's gravity pulls water back to earth during precipitation. [a]
c. Both the ocean's tides and the moon drive the flow of the water cycle.
d. Only the sun completely controls the movement of water on earth.

Table 28

PSTs' Responses by Teaching Emphasis and Percent for Item 9

		Reason									
		a		b		c		d		Total	
Emphasis	Choice	n	%	n	%	n	%	n	%	n	%
Elementary	a	0	0.0	1	2.7	0	0.0	3	8.1	4	10.8
	b	2	5.4	0	0.0	0	0.0	0	0.0	2	5.4
	c	0	0.0	0	0.0	1	2.7	0	0.0	1	2.7
	d	3	8.1	25	67.6[a]	2	5.4	0	0.0	30	81.1
	Total	5	13.5	26	70.3	3	8.1	3	8.1		
Secondary	a	0	0.0	2	5.0	0	0.0	2	5.0	4	10.0
	b	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	c	0	0.0	1	2.5	2	5.0	0	0.0	3	7.5
	d	0	0.0	32	80.0[a]	0	0.0	1	2.5	33	82.5
	Total	0	0.0	35	87.5	2	5.0	3	7.5		
Composite	a	0	0.0	3	3.9	0	0.0	5	6.5	8	10.4
	b	2	2.6	0	0.0	0	0.0	0	0.0	2	2.6
	c	0	0.0	1	1.3	3	3.9	0	0.0	4	5.2
	d	3	3.9	57	74.0[a]	2	2.6	1	1.3	63	81.8
	Total	5	6.5	61	79.2	5	6.5	6	7.8		

[a] correct choice and reason

ITEM 10

Which of the following atmospheric gas can cause an increase the greenhouse effect in the atmosphere?

a. Carbon dioxide
b. Water Vapor
c. Ozone
d. Both a and b [a]

The reason for your selection is because:

a. Increases in global population produce more of this gas.
b. Can vary depending on the season.
c. Gas can hold heat within the atmosphere. [a]
d. Allows for more sunlight to reach the earth's atmosphere.

Table 29

PSTs' Responses by Teaching Emphasis and Percent for Item 10

		Reason									
		a		b		c		d		Total	
Emphasis	Choice	n	%	n	%	n	%	n	%	n	%
Elementary	a	12	32.4	2	5.4	7	18.9	1	2.7	22	59.5
	b	0	0.0	0	0.0	1	2.7	0	0.0	1	2.7
	c	1	2.7	0	0.0	2	5.4	3	8.1	6	16.2
	d	1	2.7	1	2.7	6	16.2[a]	0	0.0	8	21.6
	Total	14	37.8	3	8.1	16	43.2	4	10.8		
Secondary	a	10	25.0	1	2.5	8	20.0	4	10.0	23	57.5
	b	0	0.0	0	0.0	1	2.5	1	2.5	2	5.0
	c	0	0.0	0	0.0	1	2.5	2	5.0	3	7.5
	d	1	2.5	1	2.5	9	22.5[a]	1	2.5	12	30.0
	Total	11	27.5	2	5.0	19	47.5	8	20.0		
Composite	a	22	28.6	3	3.9	15	19.5	5	6.5	45	58.4
	b	0	0.0	0	0.0	2	2.6	1	1.3	3	3.9
	c	1	1.3	0	0.0	3	3.9	5	6.5	9	11.7
	d	2	2.6	2	2.6	15	19.5[a]	1	1.3	20	26.0
	Total	25	32.5	5	6.5	35	45.5	12	15.6		

[a] correct choice and reason

ITEM 11

The melting of floating sea ice due to global warming will probably cause:

a. Sea level to rise
b. Sea level to fall
c. No change in current sea levels [a]

The reason for your selection is because:

a. The extra water produced due to the melting will cause sea level to rise and flood coastal areas.
b. The loss of the sea ice will lower sea level because ice weighs more than water.
c. No change in sea level will happen because sea ice and water have the same volume. [a]

Table 30

PSTs' Responses by Teaching Emphasis and Percent for Item 11

		Reason							
		a		b		c		Total	
Emphasis	Choice	n	%	n	%	n	%	n	%
Elementary	a	32	86.5	0	0.0	0	0.0	32	86.5
	b	0	0.0	1	2.7	0	0.0	1	2.7
	c	0	0.0	0	0.0	4	10.8[a]	4	10.8
	Total	32	86.5	1	2.7	4	10.8		
Secondary	a	32	80.0	1	2.5	0	0.0	33	82.5
	b	0	0.0	0	0.0	0	0.0	0	0,0
	c	0	0.0	0	0.0	7	17.5[a]	7	17.5
	Total	32	80.0	1	2.5	7	17.5		
Composite	a	64	83.1	1	1.3	0	0.0	65	84.4
	b	0	0.0	1	1.3	0	0.0	1	1.3
	c	0	0.0	0	0.0	11	14.3[a]	11	14.3
	Total	64	83.1	2	2.6	11	14.3		

[a] correct choice and reason

Movement through the Water Cycle

Factor 5 included four items: 12, 13, 14, and 15. Item 12 (Table 31) assessed the cause for changes in the rate of evaporation. EPSTs selected correctly both the content and reason at 24.3 % and the SPSTs at 30.8 %. This gave an overall mean of 27.6 %. Overall, 88.2 % of the participants selected correctly, “Decreases,” as their response to the content tier with EPSTs at 91.5 % and the SPSTs at 84.6 %, respectively. For the reason tier, 64.9 % of the EPSTs and 48.7 % SPSTs selected the same alternative response for the reason tier, “Cooler air provides a lower amount of energy for evaporation.” Overall, participants selected this alternative response as a reason at 56.6 %.

Item 13 (Table 32) assessed the PSTs’ knowledge of the greatest source of water on earth. EPSTs selected correctly both the content and reason at 83.8 % and the SPSTs at 92.5 %. This gave an overall mean of 88.3 %.

Item 14 (Table 33) assessed the total volume of water in the water cycle system. EPSTs selected correctly both the content and reason at 35.1 % and the SPSTs at 55.0 %. This gave an overall mean of 45.5 %. Overall, 31.2 % of the participants selected the incorrect alternative, “Varies over time,” for the content tier with EPSTs at 35.1 % and SPSTs at 27.5 %, respectively. For the reason tier, 40.5 % of the EPSTs and 32.5 % SPSTs selected the same incorrect alternative response, “Water cycle is an open system so the total volume of water constantly changes either up or down.” Overall, participants selected this alternative response for the reason tier at 36.4 %.

ITEM 12

When the temperature of water and the atmosphere becomes colder, the rate of evaporation:

a. Decreases [a]
b. Increases
c. Stays the same

The reason for your selection is because:

a. Cooler air provides a lower amount of energy for evaporation.
b. Cooler air provides a greater amount of energy for evaporation.
c. Rate of evaporation is not influenced by temperature.
d. Air's capacity to hold water vapor is a function of temperature. [a]

Table 31

PSTs' Responses by Teaching Emphasis and Percent for Item 12

		Reason									
		a		b		c		d		Total	
Emphasis	Choice	n	%	n	%	n	%	n	%	n	%
Elementary n = 37	a	24	64.9	1	2.7	0	0.0	9	24.3[a]	34	91.2
	b	0	0.0	1	2.7	0	0.0	0	0.0	1	2.7
	c	0	0.0	0	0.0	1	2.7	1	2.7	2	5.4
	Total	24	64.9	2	5.4	1	2.7	10	27.0		
Secondary n = 39	a	19	48.7	2	5.1	0	0.0	12	30.8[a]	33	84.6
	b	0	0.0	2	5.1	0	0.0	0	0.0	2	5.1
	c	0	0.0	0	0.0	3	7.7	1	2.6	4	10.3
	Total	19	48.7	4	10.3	3	7.7	13	33.3		
Composite n = 76	a	43	56.6	3	3.9	0	0.0	21	27.6[a]	67	88.2
	b	0	0.0	3	3.9	0	0.0	0	0.0	3	3.9
	c	0	0.0	0	0.0	4	5.3	2	2.6	6	7.9
	Total	43	56.6	6	7.9	4	5.3	23	30.3		

[a] correct choice and reason

ITEM 13

Most of the water on earth is found in:

a. Glaciers and ice caps
b. Large lakes and streams
c. Underground water
d. Oceans [a]

The reason for your selection is because:

a. Greatest volume and depth of water on earth. [a]
b. Vast amounts of water lay underneath the earth's surface.
c. Frozen water stored in Polar Regions and at higher attitudes.
d. Runoff collects fresh water sources.

Table 32

PSTs' Responses by Teaching Emphasis and Percent for Item 13

		Reason									
		a		b		c		d		Total	
Emphasis	Choice	n	%	n	%	n	%	n	%	n	%
Elementary	a	0	0.0	0	0.0	5	13.5	0	0.0	5	13.5
	b	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	c	0	0.0	1	2.7	0	0.0	0	0.0	1	2.7
	d	31	83.8[a]	0	0.0	0	0.0	0	0.0	31	83.8
	Total	31	83.8	1	2.7	5	13.5	0	0.0		
Secondary	a	0	0.0	0	0.0	2	5.0	0	0.0	2	5.0
	b	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	c	0	0.0	1	2.5	0	0.0	0	0.0	1	2.5
	d	37	92.5[a]	0	0.0	0	0.0	0	0.0	37	92.5
	Total	37	92.5	1	2.5	2	5.0	0	0.0		
Composite	a	0	0.0	0	0.0	7	9.1	0	0.0	7	9.1
	b	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	c	0	0.0	2	2.6	0	0.0	0	0.0	2	2.6
	d	68	88.3[a]	0	0.0	0	0.0	0	0.0	68	88.3
	Total	68	88.3	2	2.6	7	9.1	0	0.0		

[a] correct choice and reason

ITEM 14

The total volume of water on earth is:

a. Almost constant [a]
b. Decreasing
c. Increasing
d. Varies over time

The reason for your selection is because:

a. Water cycle is a closed system, so no water is lost or gained. [a]
b. Water cycle is an open system so the total volume of water constantly changes either up or down.
c. Water cycle is an open system that allows water to escape into the earth's interior.
d. Water cycle is an open system that allows water vapor from space to enter our atmosphere, and eventually fall to earth.

Table 33

PSTs' Responses by Teaching Emphasis and Percent for Item 14

		Reason									
		a		b		c		d		Total	
Emphasis	Choice	n	%	n	%	n	%	n	%	n	%
Elementary	a	13	35.1[a]	2	5.4	1	2.7	2	5.4	18	48.6
	b	0	0.0	2	5.4	3	8.1	0	0.0	5	13.5
	c	0	0.0	0	0.0	0	0.0	1	2.7	1	2.7
	d	1	2.7	11	29.7	1	2.7	0	0.0	13	35.1
	Total	14	37.8	15	40.5	5	13.5	3	8.1		
Secondary	a	22	55.0[a]	0	0.0	1	2.5	1	2.5	24	60.0
	b	0	0.0	2	5.0	2	5.0	0	0.0	4	10.0
	c	0	0.0	1	2.5	0	0.0	0	0.0	1	2.5
	d	0	0.0	10	25.0	1	2.5	0	0.0	11	27.5
	Total	22	55.0	13	32.5	4	10.0	1	2.5		
Composite	a	35	45.5[a]	2	2.6	2	2.6	3	3.9	42	54.5
	b	0	0.0	4	5.2	5	6.5	0	0.0	9	11.7
	c	0	0.0	1	1.3	0	0.0	1	1.3	2	2.6
	d	1	1.3	21	27.3	2	2.6	0	0.0	24	31.2
	Total	36	46.8	28	36.4	9	11.7	4	5.2		

[a] correct choice and reason

Item 15 (Table 34) assessed the components needed for cloud development. EPSTs selected correctly both the content and reason at 18.9 % and the SPSTs at 35.0 %. This gave an overall mean of 27.3 %. Overall, 35.1 % of the PSTs selected the incorrect alternative, “Ozone, water vapor, and nitrogen” for the content tier with EPSTs at 32.4 % and SPSTs at 37.5 %, respectively. For the reason tier, 32.4 % of the EPSTS and 37.5 % SPSTs selected the same incorrect alternative response, “Atmospheric conditions needed for cloud formation.” Overall, PSTs selected this alternative response for the reason tier at 35.1 %.

Confidence Tier

The third tier used a four-point Likkert scale to determine the PSTs’ confidence on the WCDT. PSTs rated how confident they were about their answers to both tiers, content and reason. Table 35 shows the descriptive statistics of the PSTs’ confidence ratings for each item on the WCDT. EPSTs had a mean confidence rating of 2.36 (*SD* = 0.39), and the SPSTs had a mean of 2.54 (*SD* of 0.38). Overall, PSTs had a confidence rating of 2.45 (*SD* = 0.37), respectively. EPSTs had their highest confidence on item 13 at 3.03 (*SD* = 0.76) which dealt with the greatest source of water on earth, and their lowest confidence was item 3 with 1.73 (*SD* = 0.69) which dealt with latent heating and the phase change of water. SPSTs’ highest confidence rating occurred on item 4 with a 3.15 (*SD* = 0.98), which was concerned with condensation, and they also had their lowest confidence on item 3 with 1.83 (*SD*= 0.81) that dealt with latent heating and the phase change of water.

ITEM 15

What is needed for clouds to develop?

a. Water vapor and atmospheric dust [a]
b. Ozone, water vapor, and nitrogen
c. Low pressure with low relative humidity
d. Oxygen and hydrogen

The reason for your selection is because:

a. Essential elements needed to form water.
b. Dust allows water droplets to come together. [a]
c. Influenced by a variety of atmospheric gases in order to form.
d. Atmospheric conditions needed for cloud formation.

Table 34

PSTs' Responses by Teaching Emphasis and Percent for Item 15

		Reason									
		a		b		c		d		Total	
Emphasis	Choice	n	%	n	%	n	%	n	%	n	%
Elementary	a	0	0.0	7	18.9[a]	0	0.0	3	8.1	10	27.0
	b	2	5.4	0	0.0	5	13.5	5	13.5	12	32.4
	c	0	0.0	0	0.0	2	5.4	3	8.1	5	13.5
	d	6	16.2	0	0.0	3	8.1	1	2.7	10	27.0
	Total	8	21.6	7	18.9	10	27.0	12	32.4		
Secondary	a	1	2.5	14	35.0[a]	0	0.0	2	5.0	17	42.5
	b	0	0.0	0	0.0	8	20.0	7	17.5	15	37.5
	c	0	0.0	0	0.0	0	0.0	6	15.0	6	15.0
	d	2	5.0	0	0.0	0	0.0	0	0.0	2	5.0
	Total	3	7.5	14	35.0	8	20.0	15	37.5		
Composite	a	1	1.3	21	27.3[a]	0	0.0	5	6.5	27	35.1
	b	2	2.6	0	0.0	13	16.9	12	15.6	27	35.1
	c	0	0.0	0	0.0	2	2.6	9	11.7	11	14.3
	d	8	10.4	0	0.0	3	3.9	1	1.3	12	15.6
	Total	11	14.3	21	27.3	18	23.4	27	35.1		

[a] correct choice and reason

Table 35

PSTs' Confidence Ratings' by Teaching Emphasis with Overall Confidence Mean Per Item and Standard Deviation

Item	EPSTs	*SD*	SPSTs	*SD*	PSTs	*SD*
1	2.00	0.78	2.58	0.96	2.29	0.41
2	2.22	0.85	2.28	1.06	2.25	0.04
3	1.73	0.69	1.83	0.81	1.78	0.07
4	2.97	0.76	3.15	0.98	3.06	0.13
5	2.41	0.80	2.65	0.74	2.53	0.17
6	2.57	0.93	2.63	1.01	2.60	0.04
7	1.92	0.83	2.08	0.92	2.00	0.11
8	2.46	0.77	2.45	0.82	2.46	0.01
9	2.51	0.93	2.78	0.83	2.65	0.19
10	2.22	0.92	2.53	0.88	2.38	0.22
11	2.84	0.80	3.08	0.88	2.96	0.17
12	2.38	0.86	2.60	0.98	2.49	0.16
13	3.03	0.76	2.93	0.86	2.98	0.07
14	2.22	0.82	2.58	0.93	2.40	0.26
15	1.89	0.88	1.98	0.80	1.94	0.26
Total	2.36	0.39	2.54	0.38	2.45	0.37

PSTs' Representations of the Water Cycle

Eight voluntary PSTs, four each from the EPSTs and SPSTs, were randomly selected for an interview after the completion of preliminary analysis of the WCDT scores. Each interviewee had to fit into one of the following categories developed in the matrix (Table 36) below when comparing their WCDT score and overall confidence rating to the other PSTs' overall means and standard deviations.

Table 36

Developed Matrix for PSTs Selection for Water Cycle Interviews

	High Confidence (+ 1 *SD*)	Low Confidence (– 1 *SD*)
High Score on WCDT (+1 *SD*)	High WCDT Score and High Confidence	High WCDT Score and Low Confidence
Low Score on WCDT (-1 *SD*)	Low WCDT Score and High Confidence	Low WCDT Score and Low Confidence

Interviewees were asked to draw their representation of the water cycle. Each participant was given colored pencils and pens to use for their drawing. No time limit was given for completion of this task. Figure 7 is an example of one of the PSTs' drawings, who had a high WCDT score and a low confidence rating: the other PSTs' drawings can be found in Appendix E. After completion of their water cycle representation, participants were asked to elaborate on the features they drew and on whether or not they had an understanding of those processes listed within their drawing. After the initial explanation by the interviewee, the researcher asked the participants about the water cycle processes not represented within their drawing. At the end of the interview, the researcher asked participants about their overall confidence in teaching the water cycle in future classrooms. Drawings were analyzed using a rubric developed by Schaffer and Barrow (2011) for evaluating water cycle representations. The rubric scores the ten essential features of the water cycle that should be represented when illustrated and described in a representation. A "yes" score in a features means that feature was represented, and a "no" score means that it was not represented. The total score is the number of essential features represented. After initial scoring of the representations, another evaluator scored the representations. All representations obtained the same scores for a 100 percent inter-rater reliability.

Table 37 is the breakdown of the scores on the water cycle representations. EPSTs that were interviewed averaged 2.75 essential features in their drawings for 27.5 %, while the SPSTs who were interviewed have 3.75 essential features in their water cycle representations for a 37.5 %. Overall, the mean for the PSTs' drawings was 3.25 (*SD* = 1.48). Table 38 shows the number of times each essential feature was included in the participants' representations. EPSTs and SPSTs included water storage as an essential feature 87.5 % of the time. The following were not represented in any of the participants'

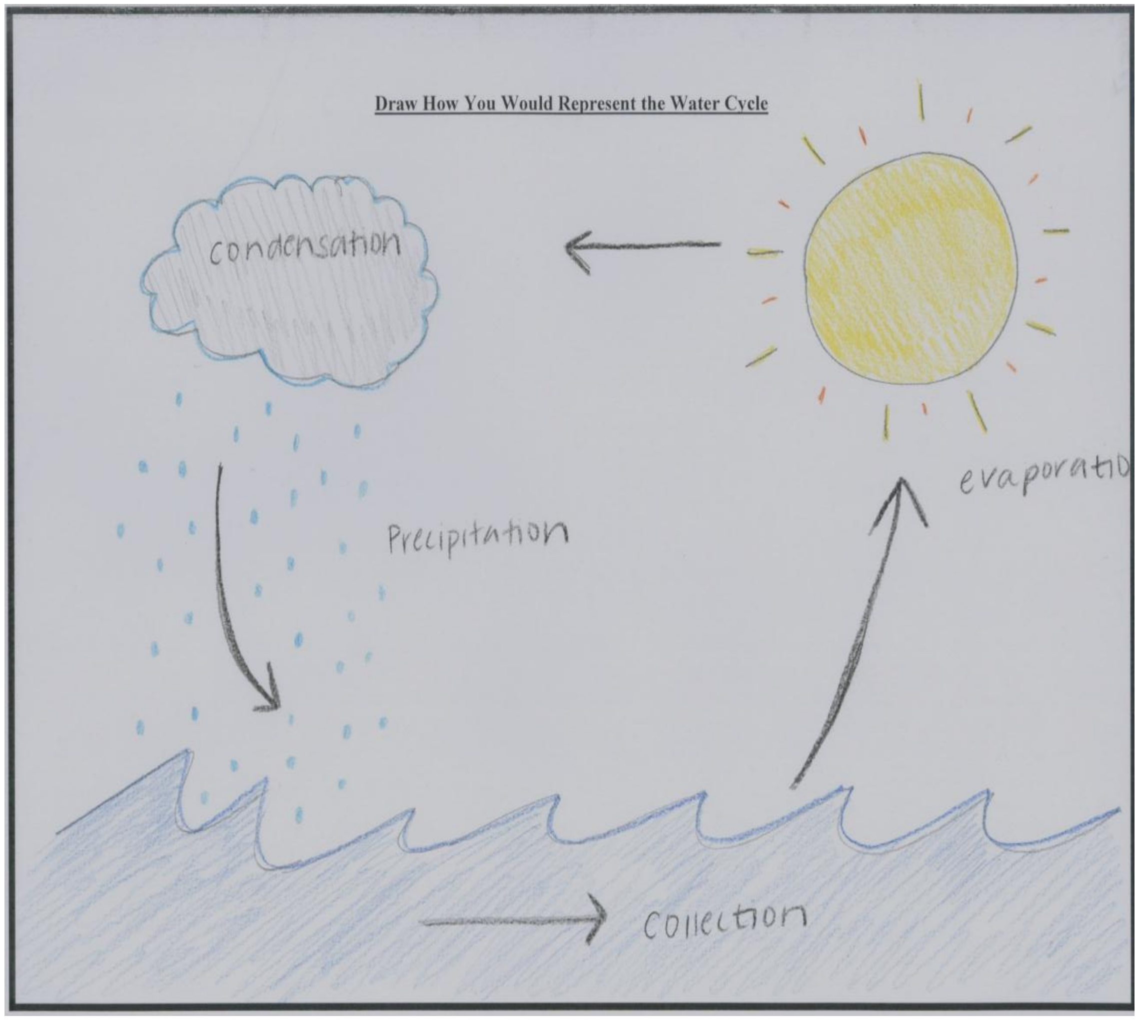

Figure 7. Representation of the Water Cycle by an EPST with a High Score on the WCDT and Low Confidence.

drawings: precipitation depicted over both the ocean and land, transpiration from plants, and life processes from animals and plants.

Table 37

Interviewees' Score on Water Cycle Representation Drawings

	Educational Emphasis			
	EPSTs		SPSTs	
Participant	No. Correct	%	No. Correct	%
High WCDT Score, High Confidence	4	40.0	6	60.0
High WCDT Score, Low Confidence	3	30.0	4	40.0
Low WCDT Score, High Confidence	2	20.0	4	40.0
Low WCDT Score, Low Confidence	2	20.0	1	10.0
Mean	2.75	27.5	3.75	37.5

Table 38

Number and Percent of Essential Features Depicted in Participants' Drawings

Essential Feature	# Correct by EPSTs	# Correct by SPSTs	Total Correct	Percent %
Sun depicted	3	1	4	50.0
Evaporation depicted coming from both land and from the ocean	1	2	3	37.5
Precipitation shown occurring on the land and the ocean	0	0	0	0.0
Condensation of water vapor	3	1	4	50.0
Transpiration from plants	0	0	0	0.0
Infiltration/Seepage/Percolation into sub-surfaces	0	2	2	25.0
Runoff of water	1	2	3	37.5
Groundwater	0	3	3	37.5
Water storage	3	4	7	87.5
Life processes depicting animals and plants involvement	0	0	0	0.0

Additional statistical analysis was conducted on the interview data to examine if there was a relationship between the PSTs' overall score on their representations with their WCDT score and confidence rating. Interviewees had an overall mean score on the WCDT of 5.25 (*SD* =2.86). The overall mean of the interviewees' confidence ratings was 2. 13 (*SD* = 0.58). The PSTs' water cycle representations scores were correlated on the PSTs' WCDT scores and confidence ratings. These two predictors accounted for almost three quarters of the variance in the WCDT scores ($R^2 = 0.7315$), which was significant, $F(2, 7) = 6.81$, $\rho = 0.04$. The WCDT scores ($\beta = 0.76$, $\rho = 0.01$) demonstrated a significant effect on the PSTs' water cycle representations, but the PSTs' confidence ratings ($\beta = 0.27$, $\rho = 0.31$) did not have a significant effect on the PSTs' drawings.

Inferential Statistics

This section describes the tests of the null hypotheses using one-way ANOVA and regression. Independent variables in this study included the WCDT's third-tier confidence ratings, PSTs' CBASE scores, and demographic survey. These included when the PSTs last studied the water cycle, if they completed an atmospheric science course as an undergraduate, when they last studied Earth Science, usage of media sources pertaining to obtaining weather information, and if the PSTs have experienced any severe weather phenomena. Gender was not be used as an independent variable due to a low sample size of males involved in the study ($n = 18$). The dependent variable for the study was the EPSTs and SPSTs' score on the WCDT.

The first null hypothesis tested for the differences between the EPSTs' and SPSTs' scores on the WCDT regarding their conceptual understanding of the water cycle. A one-way ANOVA demonstrated a very significant difference for the main effect of teaching emphasis for the WCDT, F (1, 75) = 11.33, ρ = 0.001 (Table 39). This indicates that there was a significance difference between the EPSTs and the SPSTs on their WCDT mean scores, with the SPSTs outperforming EPSTs on the WCDT. Therefore, the first hypothesis was rejected. However, the effect size (η^2 = 0.13) was small, which meant that only 13.1 % of the variability in the PSTs' WCDT score can be accounted for by the differences in teaching emphasis.

Table 39

One-way ANOVA between ESPTs and SPSTs' Scores on the WCDT

	SS	*df*	*MS*	*F*	*ρ*
Between Groups	46.06	1	46.06	11.33	0.001
Within Groups	304.75	75	4.063		
Total	350.81	76			

The second hypothesis tested for differences between EPSTs' and SPSTs' scores on the WCDT and their confidence regarding their conceptual understanding of the water cycle. The one-way ANOVA demonstrated a significant difference for the main effect of educational emphasis, F (1, 152) = 180.59, ρ < 0.0001 (Table 40). This indicates that there was a significant difference between EPSTs and SPSTs on for the mean scores of the confidence ratings on the WCDT with the SPSTs having a greater confidence in their answers on the first two tiers of the WCDT than the EPSTs. Therefore, the second hypothesis was rejected. The effect size (η^2 = 0.54) was large, which meant that 54.3 % of the variability in the PSTs' WCDT score can be accounted for by their confidence.

Table 40

One-way ANOVA between EPSTs and SPSTs' Scores and their Confidence on the WCDT

	SS	*df*	*MS*	*F*	*ρ*
Between Groups	439.701	1	439.701	180.59	<.0001
Within Groups	370. 089	152	2.435		
Total	809.790	153			

The third and fourth hypotheses (Table 41) were developed to test for correlations between the EPSTs' and SPSTs' CBASE science scores with their scores on the WCDT, respectively. For the third hypothesis, the correlation coefficients indicated that the scores on CBASE were not significant with the scores received by the EPSTs on the WCDT using Cohen's (1988) Guidelines, r = 0.18. The fourth hypothesis was also not significant for SPSTs concerning their CBASE scores and the scores on the WCDT. The correlation, r = 0.29, was also considered a small relationship by those same guidelines. Therefore, neither the third nor the fourth hypotheses were rejected.

Table 41

Linear Regression for Correlations between CBASE scores and the WCDT by Teaching Emphasis

Teaching Emphasis	n	*df*	r^2	Slope	Y Intercept	t	r	ρ
Elementary	33	31	0.03	0.008	2.69	1.03	0.18	0.311
Secondary	40	38	0.08	0.011	2.71	1.86	0.29	0.071

The next set of hypotheses (fifth, sixth, and seventh) deals with the correlation of demographic questions asked and the PSTs' scores on the WCDT (Table 42) using linear regression. The fifth hypothesis was developed to test for the correlation between EPSTs' and SPSTs' scores from the WCDT and the when they last studied the water cycle in school. The correlation coefficient (r = 0.22) indicated that the scores on the WCDT had only a small correlation with when the PSTs last studied the water cycle, and no statistical significance (ρ = .06) on the main effect, WCDT scores. Therefore, the fifth hypothesis was not rejected.

Table 42

Correlations between Participants' Answers to the Questions 1, 2, and 3 on the Demographic Survey and Scores on the WCDT

Question	r	r^2	Slope	Y Intercept	Std. Err. of Estimate	t	df	ρ
Last Studied the Water Science	0.22	0.05	0.14	2.24	1.36	1.91	75	0.06
ATMS as an Undergraduate	0.31	0.10	0.05	-0.15	0.34	2.83	75	0.006
Studied Earth Science	0.18	0.03	0.10	2.83	1.24	1.58	75	0.12

The sixth hypothesis examined the correlation between the WCDT scores of EPSTs and SPSTs who have studied the water cycle as undergraduates in either an atmospheric science and/or meteorology course and those PSTs who last studied the water cycle during their K-12 education. Demographic statistics showed that none of the EPSTs (*M* = 0.0, *SD* = 0.0) has taken a course in atmospheric science and/or meteorology prior to taking the WCDT, but 11 (27.5 %) of the SPSTs (*M* = 0.28, *SD* = 0.45) who had completed a course in atmospheric science and/or meteorology. Those SPSTs who have taken a course in atmospheric science and/or meteorology had a mean score of 7.45 (*SD* = 1.78) on the WCDT, and those SPSTs who did not, had a mean score of 6.24 (*SD* = 1.83). The correlation coefficient (r = 0.31) indicated that taking an atmospheric science and/or meteorology course prior to taking the WCDT had a medium correlation when the PSTs took a course in atmospheric science and/or meteorology prior to taking the WCDT with a statistically significance (ρ = .006) on the main effect, the WCDT scores. Therefore, the sixth hypothesis was rejected.

The seventh hypothesis examined the correlation between the EPSTs' and SPSTs' scores on the WCDT and when PSTs were last enrolled in an Earth Science course in school. The correlation coefficient ($r = 0.18$) indicated that the scores on the WCDT had no relationship with when the PSTs were last enrolled in an Earth Science course in school, and no statistical significance ($\rho = .12$) on the main effect, the WCDT scores. Therefore, the seventh hypothesis was not rejected.

The eighth hypothesis examined the correlation between the WCDT scores of EPSTs and SPSTs who have a higher interest in listening and/or viewing weather-related media than those PSTs who have a lower interest weather related media using regression. PSTs rated their usage of the following media sources to obtain weather-related information: local radio, local television, *TWC*, *TWC*-Website, use of NOAA weather radio, use of a cell phone app, the internet, and other social media. Table 43 reports the correlation between the types of media usage the PSTs rated and the scores on the WCD. The significance of the correlation values was calculated using the following non-directional hypothesis for the Pearson Coefficient:

H_o: $\rho = 0$ H_1: $\rho \neq 0$ $\alpha = .01$ $df = 77$

$r_{critical} = \pm .2866$ If $[r_{observed}] \geq [r_{critical}]$ then Reject H_o

The PSTs' scores from WCDT had a medium inverse correlation ($r = -.32$) with social media. This represents that PSTs with a higher total score on the WCDT usually rated their use of social media as low as when compared to individuals with a lower total

Table 43

Inter-correlations of the PSTs' Media Usage with Scores on the WCDT

Subscale	1	2	3	4	5	6	7	8	9
1. WCDT Score	_	.01	-.10	-.05	.15	.15	-.20	-.10	-.32*
2. Local Radio		_	.23	-.03	.07	.41*	.18	-.18	.23
3. Local Television			_	.40*	.17	.12	.40*	.23	.20
4. *TWC* on TV				_	.28	-.04	.13	.08	.08
5. *TWC* on the Web					_	-.00	.06	.67*	.04
6. NOAA Weather Radio						_	-.08	.21	.21
7. Cell Phone App							_	.09	.10
8. Internet								_	.10
9. Social Media									_

*$p < .01$

score on the WCDT who rated their usage of social media to obtain weather-related information as high. None of the other media sources had a significant relationship with the WCDT, but several media sources had significant relationships with one another. Included was a very large correlation between *TWC* from the web and the internet (r = 0.67), and several others had medium correlations with media sources which included: local radio with the use of the NOAA weather radio (r = .41), and local television with both *TWC* on TV (r = .40) and the use of cell phone apps (r = 0.40).

The analysis shows that the use of media to obtain weather-related information had significantly predicted the PSTs' scores on the WCDT. The results of the regression (Table 44) indicated that the predicators explained 21.0 % of the variance ($R^2 = .21$, F (8, 68) = 2.21, ρ = .037). Overall, the main effect (Table 45) of media usage to obtain weather-related information on the PSTs' scores on the WCDT was significant, *F* (8, 76) = 2.21, ρ = .037. Therefore, the eighth hypothesis was rejected.

Table 44

Regressed Statistics for the Eighth Null Hypothesis Concerning PSTs' Usage of Media for Weather-related Information and their Scores on the WCDT

				Change Statistics				
R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df_1	df_2	Sig. F Change
.454	.206	.113	2.024	.206	2.209	8	68	.037*

*ρ < 0.05, **ρ< 0.01

Table 45

ANOVA for the Eighth Null Hypothesis Concerning PSTs' Usage of Media for Weather-related Information and their Scores on the WCDT

	SS	*df*	*MS*	*F*	*ρ*
Regression	72.355	8	9.044	2.209	.037
Residual	278.451	68	4.095		
Total	350.805	76			

The ninth hypothesis examined the correlation between the scores of EPSTs and SPSTs on the WCDT and their experiences of severe weather phenomena using regression. PSTs reported if they had experienced any of the following severe weather phenomena: a tornado, a hurricane, flooding, hail greater than two inches, a blizzard, a snow avalanche, being struck by lightning (themselves, family, and/or home), a mudslide, and a drought. Table 46 reports the correlation between the severe weather phenomena experienced by the PSTs and the scores on the WCD.

None of the severe weather phenomena had a significant correlation with the PSTs' scores from the WCDT. However, several severe weather phenomena had correlations with one another. These include the PSTs experiencing hurricanes that had a small significant correlation with snow avalanche ($r = .29$), and a higher medium correlation with mudslides ($r = .49$). Another medium correlation occurred between experiencing a snow avalanche and mudslides ($r = .39$). The $r_{critical}$ value of .2866 for Pearson's Correlation Coefficient was used for significance ($\rho < .01$).

The analysis shows that experiencing severe weather phenomena for the PSTs had no significance on the PSTs' scores from the WCDT. The results of the regression (Table 47) indicated that the predicators explained 15.4 % of the variance ($R^2 = .15$, $F(7, 67) = 1.36$, $\rho = .23$). Overall, the main effect (Table 48) of experiencing severe weather phenomena on the PSTs' scores on the WCDT was not significant, $F(9, 76) = 1.36$, $\rho = .23$. Therefore, the ninth hypothesis was not rejected.

Table 46

Inter-correlations of the PSTs' Experiences with Severe Weather and their Scores on the WCDT

Subscale	1	2	3	4	5	6	7	8	9	10
1. WCDT Score	_	.10	.05	-.04	-.02	.09	-.03	-.11	.24	.24
2. Tornado		_	.21	-.00	.19	.14	.13	.17	.16	.24
3. Hurricane			_	.14	.19	-.06	.29*	.04	.49*	.10
4. Flooding				_	.02	.09	-.01	.01	.05	.16
5. Hail greater than two inches					_	.00	.12	.14	.15	-.10
6. Blizzard						_	-.01	-.13	.06	.07
7. Snow Avalanche							_	.17	.39*	.03
8. Struck by Lightning								_	.11	.11
9. Mudslides									_	.10
10. Drought										_

*p < .01

Table 47

Regressed Statistics for the Eighth Null Hypothesis Concerning PSTs' Experiencing Severe Weather Phenomena and their Scores on the WCDT

				Change Statistics				
R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df_1	df_2	Sig. F Change
.393	.154	.041	2.104	.154	1.358	9	67	.225

$*\rho < 0.05$, $**\rho < 0.01$

Table 48

ANOVA for the Eighth Null Hypothesis Concerning PSTs' Experiencing Severe Weather Phenomena and their Scores on the WCDT

	SS	*df*	*MS*	*F*	*ρ*
Regression	54.120	9	6.013	1.358	.225
Residual	296.685	67	4.428		
Total	350.805	76			

Individual Item Analysis

Using an independent two-tailed t-test, each group's means were compared by item on the WCDT. Results (Table 49) show that for every item on the WCDT, except item 6, the ESPs had a lower mean score than the SPSTs. Item 6 checked for the PSTs' understanding of source areas for the atmosphere to obtain moisture. EPSTs had mean of 0.89 (*SD* = 0.31), and the SPTs (*M* = 0.88, *SD* = 0.33) for item 6. Two additional items were considered significant when comparing the two groups' item mean scores; they were items 3 and 7. Item 3 examined the PSTs' understanding of latent heating and the phase changes of water. The EPSTs had a mean of 0.0 (*SD* = 0.0) and the SPTs (*M* = 0.1, *SD* = 0.3) for a significant difference, t (75) = -2.0, ρ = 0.049. Item 7 dealt with the PSTs' understanding of clouds in which the ESPs' mean score was 0.22 (*SD* = 0.41) while the SPTs had a mean of 0.46 (*SD* = 0.5) for a significant difference, t (75) = -2.21, ρ = 0.03.

Table 49

Independent Two-tailed T-test Results for Items on the WCDT

Item	*df*	t	ρ
1	75	-0.94	0.35
2	75	-1.94	0.10
3	75	-2.00	0.049
4	75	-1.78	0.08
5	75	-.08	0.94
6	75	0.23	0.82
7	75	-2.21	0.03
8	75	-1.49	0.14
9	75	-1.24	0.22
10	75	-0.69	0.49
11	75	-.083	0.41
12	75	-0.55	0.58
13	75	-1.18	0.24
14	75	-1.76	0.08
15	75	-1.59	0.12

Summary of the Findings

Null Hypotheses

The quantitative results involved data received from 77 PSTs during the fall of 2012. Table 50 gives an overview of all the tested hypotheses developed for this study and indicates the statistical test used for each hypothesis, whether or not a hypothesis was rejected, and the significance. The results of the one-way ANOVA performed for the first hypothesis indicated that there was a statistically significant difference between the EPSTs' and the SPSTs' scores on the WCDT with the SPSTs outperforming the ESPTs on the WCDT. A one-way ANOVA was also performed for the second hypothesis and statistically significant difference was found between the ESPTs' and the SPSTs' confidence ratings for the WCDT. Results indicated that the SPTs had significantly higher confidence in their answers than the EPSTs for the WCDT. Regression analysis

Table 50

Summary of the Null Hypotheses Including Statistical Analysis Conducted, Status of Rejection, and Significance

Null Hypotheses	Statistical Analysis Conducted	Rejected or Not Rejected	p
H_{O1}: There is no statistically significant difference between EPSTs' and SPSTs' scores on the WCDT regarding their conceptual understanding of the water cycle.	ANOVA	Rejected	.0001
H_{O2}: There is no statistically significant difference between EPSTs' and SPSTs' scores on the WCDT and their confidence regarding their conceptual understanding of the water cycle.	ANOVA	Rejected	<.0001
H_{O3}: There is no statistically significant correlation between EPSTs' scores from the WCDT and their science scores on the *CBASE.*	Linear Regression	Not Rejected	.311
H_{O4}: There is no statistically significant correlation between SPSTs' scores from the WCDT and their science scores on the *CBASE.*	Linear Regression	Not Rejected	.071
H_{O5}: There is no statistically significant correlation between EPSTs' and SPSTs' scores from the WCDT and when they last studied the water cycle.	Linear Regression	Not Rejected	.06
H_{O6}: There is no statistically significant correlation between the WCDT scores of EPSTs and SPSTs who studied the water cycle as undergraduates and those PSTs who last studied the water cycle on the K-12 level.	Linear Regression	Rejected	.006

(*Continued*)

Table 50

Continued

H_{O7}: There is no statistically significant correlation between EPSTs' and SPSTs' scores from the WCDT and when those PSTs were last studied Earth Science.	Linear Regression	Not Rejected	.12
H_{O8}: There is no statistically significant correlation between the WCDT scores of EPSTs' and SPSTs' who have a higher interest in listening and/or viewing weather-related media than those PSTs who have a lower interest in weather-related media.	Multiple Regression	Rejected	.037
H_{O9}: There is no statistically significant correlation between the WCDT scores of EPSTs' and SPSTs' that have experienced severe weather events than those pre-service teachers that have not experienced severe weather events.	Multiple Regression	Not Rejected	.225

was used for the rest of the hypotheses. In regards to PSTs' CBASE scores having a relationship with their WCDT scores (null hypotheses 3 and 4), analysis showed that both the ESPTs and the SPSTs had small insignificant correlations between their CBASE and WCDT scores. Therefore, a relationship between the PSTs' WCDT scores and CBASE scores could not be found.

The next five hypotheses deal with the PSTs' scores on the WCDT and their answers on the demographic survey. The fifth hypothesis analyzed when the PSTs last studied the water cycle and its relationship to the PSTs' WCDT scores. A small correlation indicated that there was not a significant relationship between the PSTs' scores and when they last studied the water cycle. The sixth hypothesis had a moderate significant correlation. This was reflected in the higher scores on the WCDT for the PSTs who completed an undergraduate course in atmospheric science and/or meteorology. This means that if you completed a course in atmospheric science and/or meteorology the more likely the PST had a higher score on the WCDT.

The seventh hypothesis examines the relationship between the PSTs' scores on the WCDT and when they were last enrolled in an Earth Science course. The results showed a small insignificant difference between the PSTs' WCDT scores and when the PSTs were last enrolled in an Earth Science course. The eighth hypothesis investigated the relationship the WCDT PSTs' scores and the PSTs' use of different media sources to obtain weather-related information. Results showed a moderate correlation that was significant between the PSTs' scores on the WCDT and their use of media sources to obtain weather-related information. This means that the more a PST used media to obtain weather-related information, the greater likelihood that the PST had a higher score on the WCDT. The ninth hypothesis explored the relationship between the PSTs' scores on the WCDT and their severe weather phenomena experiences. The analysis showed a moderate insignificant correlation.

Alternative Conceptions

The analysis of the PSTs' responses revealed 49 possible alternative conceptions related to both the content (Table 51) and reason (Table 52) tiers on the WCDT. The selection of possible alternative conceptions was determined by the breakdown of the PSTs' scores on each item. An incorrect response of 10.0 % and greater generated an inventory included for this study. The level of 10.0 % has been established by several other researchers (e.g., Chandrasegaran, Treagust, and Mocerino, 2007; Odom and Barrow, 1995; Wang, 2007).

Twenty-three of those potential alternative conceptions were documented from the PSTs' responses from the content tier, and 26 from the reason tier. Item 1 and 6 generated the most diagnosed alternative conceptions with six each. Those questions covered the concepts of deposition and cloud formation, respectively. Items 6, 12, and 13 generated very few problematic areas from the PSTs' responses. Item 6, which dealt with water storage, had a low difficulty (Δ) of 8.24 which resulted from 88.3 % of the PSTs getting the item correct. Item 12 covered the concept of rate of evaporation, and had a higher Δ of 15.42 due the PSTs getting the content tier correct at 88.2 %, but only 30.3 % of the PSTs selected the correct response for the reason tier. Item 13 examined the PSTs'

Table 51

Summary of the PSTs' Potential Alternative Conceptions Identified from the Content Tier of the WCDT

Factor With Concept	Alternative Conceptions Identified from the Content Tier	Incorrect %
1. Phase change of water		
Deposition	"Condensation" rather than "Deposition"	34.2
	"Temperature change" rather than "Deposition"	22.3
	"Sublimation" rather than "Deposition"	17.1
Major Greenhouse Gas	"Carbon dioxide" rather than "Water Vapor"	68.8
	"Methane" rather than "Water Vapor"*	10.8
Latent Heat and Phase Changes of Water	"Convection" rather than "Phase changes of water"	45.5
	"Radiation" rather than "Phase changes of water"	25.9
	"Conduction" rather than "Phase changes of water"	23.4
2. Condensation and Storage		
Condensation	"From the beverage and ice condensing inside the can." rather than "From the air outside the beverage."	18.2
Condensation/Atmosphere	"Warms" rather than "Cools"	27.3
3. Clouds		
Naming of Clouds	"Height" rather than "Both form and height"*	13.5
	"Form" rather than "Both form and height"*	10.8
Clouds and Phase Change of Water	"Water in clouds never freezes." rather than "At 32˚F/0˚C and temperatures below 32˚F/0˚C."	44.2

*EPSTs, **PSTs (*Continued*)

Table 51

Continued

4. Global Climate Change		
Energy and Forces Propelling the Movement of the Water Cycle	"The heat from the sun" rather than "Both a and b" (The heat from the sun and the gravitational attraction from the moon)	10.4
Greenhouse Gases and Effect	"Carbon dioxide" rather than "Both a and b" (Carbon dioxide and Water Vapor)	58.4
	"Ozone" rather than "Both a and b" (Carbon dioxide and water vapor)	11.7
Melting of Sea Ice and Conservation	"Sea level to rise" rather than "No change in current sea levels"	84.4
5. Movement through the Water Cycle		
Water Storage Source	"Glaciers" rather than " Oceans"*	13.5
Total Volume of the Water Cycle	"Varies over time" rather than "Almost constant"	31.2
	"Decreasing" rather than "Almost constant"	11.7
Cloud Formation Needs	"Ozone, water vapor, and nitrogen" rather than "Water vapor and atmospheric dust"	35.1
	"Oxygen and hydrogen" rather than "Water vapor and atmospheric dust"	15.6
	"Low pressure with low relative humidity" rather than "Water vapor and atmospheric dust"	14.3

*EPSTs, **PSTs

Table 52

Summary of the PSTs' Potential Alternative Conceptions Identified from the Reason Tier of the WCDT

Factor With Concept	Alternative Conceptions Identified from the Reason Tier	Incorrect %
1. Phase change of water		
Deposition	"Happens when water vapor changes into ice and the temperature is below 32°F/0°C."	54.5
	"Happens when water changes to ice near the earth's surface when the temperature is near or below 32°F/0°C."	20.8
	"The air temperature falls below 32°F/0°C."	13.0
Major Greenhouse Gas	"Gained through the processes of excretion and respiration by animals."	36.4
	"Gained through the process of transpiration by plants."	18.2
Latent Heat and Phase Changes of Water	"When the sun's energy provides heating for the atmosphere."	59.7
	"When water particles come into contact with one another and transfer energy."	10.4
2. Condensation and Storage		
Condensation	"The beverage warmed and caused water to condensate inside the can, and the extra water caused too much volume in the can and seeped out."	15.6
Condensation/Atmosphere	"Condensation is a warming process like high humidity on a warm summer day."	18.2
	"Water warms to its vaporization point and condensation occurs."	14.3
	"Condensation is a cooling process like low humidity on a warm summer day."	11.7

*EPSTs, **PSTs (*Continued*)

Table 52

Continued

3. Clouds		
Naming of Clouds	"When a cloud name starts with "alto-" it means low in atmosphere."	30.3
	"Stratus clouds usually cause precipitation."	19.7
	"Cumulus clouds form horizontally to the earth's surface."	10.5
Clouds and Phase Change of Water	"Water droplets cool while falling to earth, and change into ice."	68.8
	"Water vapor does not freeze in clouds."	13.0
4. Global Climate Change		
Energy and Forces Propelling the Movement of the Water Cycle	"Any movement on earth is controlled by its' own gravitational forces."*	13.5
Greenhouse Gases and Effect	"Increases in global population produce more of this gas."	32.5
	"Allows for more sunlight to reach earth's atmosphere."	15.6
Melting of Sea Ice and Conservation	"The extra water produced due to the melting will cause sea level to rise and flood coastal areas."	83.1
5. Movement through the Water Cycle		
Rate of Evaporation	"Cooler air provides a lower amount of energy for evaporation."	56.6
Total Volume of the Water Cycle	"Water cycle is an open system so the total volume of water constantly changes either up or down."	36.4
	"Water cycle is an open system that allows water to escape into the earth's interior."	11.7

*EPSTs, **PSTs (*Continued*)

Table 52

Continued

Cloud Formation Needs	"Atmospheric conditions needed for cloud formation."	35.1
	"Influenced by a variety of atmospheric gases in order to form."	23.4
	"Essential elements needed to form water."	14.3

*EPSTs, **PSTs

understanding of water storage on earth, and had a low Δ of 8.24 because 88.3 % correctly answered both tiers of the WCDT.

Five possible alternative conceptions were generated only from the EPSTs' responses, and not found to be problematic from the SPSTs' responses. Four of those likely alternative conceptions were generated from the content tier, and one from the reason tier. Items 2, 7, 9, and 13 were involved with two of those alternative conceptions coming from item 7. This item tested the PSTs understanding of how clouds are named. Both of those alternative conceptions came from the content tier.

Summary

This chapter included the analysis of data from 77 PSTs that participated voluntarily in this research study. The first section provided descriptive statistics for the questions asked within the demographic survey, and whether there was a relationship between those answers and the PSTs' scores on the WCDT. The second section presented the descriptive statistics for the WCDT. The third gave a detailed analysis of the individual items on the WCDT along with PSTs' confidence ratings. The fourth included an examination of results from the PSTs' interviews in which participants were asked to draw their own representation of the water cycle, and then those responses were correlated to their WCDT scores. The fifth portion dealt with the inferential statistics from the item analysis, and the testing of the null hypotheses. The sixth and final section of this chapter gave a summary of the null hypotheses, and then an overview of the potential alternative conceptions found during the statistical analysis of items on the WCDT.

CHAPTER FIVE

CONCLUSIONS AND IMPLICATIONS

This chapter includes a summary of the study along, along with the research questions that guided the study, conclusions made from the analysis of data, a discussion about the PSTs' alternative conceptions, and recommendations for future research using the WCDT.

Summary of the Study

This study involved the development and application of a three-tier diagnostic test measuring pre-service teachers' (PSTs) understanding of the water cycle (WCDT). The WCDT used the theoretical framework by Treagust (1986, 1988, and 1995) for developing diagnostic tests. The developmental framework had three stages: defining the content, researching information on students' alternative conceptions, and developing an instrument on the water cycle. Data for the alternative conceptions was also collected from interviews and multiple-choice questions with free response answers that aided in developing the instrument. Prior to administering the instrument (32 items) to the PSTs, a third tier was added to examine the PSTs' certainty of response. After item and factor analysis of the data was completed, a 15 three-tier multiple choice instrument was finalized, in which the first tier examined content knowledge, the second tier examined the reason for that understanding of knowledge, and the third tier examined the PSTs' confidence for their responses in the first two tiers. The conceptual knowledge examined was factored into the following five areas: Phase Change of Water; Condensation and Storage; Clouds; Global Climate Change; and Movement through the Water Cycle.

The diagnostic WCDT instrument was administered to 77 PSTs (37 EPSTs and 40 SPSTs) enrolled in several science methods classes. The WCDT was not given in conjunction with a classroom invention or in a pre-test/ posttest situation. Analysis of the PSTs' responses demonstrated acceptable item reliability ($\alpha = 0.62$) for the instrument, with overall appropriate difficulty indices and acceptable discrimination indices for 12 of the 15 items on the WCDT. Each item was analyzed to determine PSTs' understanding of, and to identify alternative conceptions about the water cycle. Statistical analysis of the null hypotheses included the use of one-way ANOVAs, independent t-tests, and both linear and multiple regression.

The selection of PSTs as the study's focus was determined by the lack of previous research studies concerning PSTs' conceptual knowledge of the water cycle. At this time, only one study specifically focused upon PSTs' alternative conceptions of the water cycle (Morrell & Schepia, 2009). Other studies have centered on the water cycle, but only examined children's knowledge of the water cycle (e.g., Bar, 1989; Ben-zvi-Assarf & Orion, 2005; Shepardson et al., 2009; Taiwo, 1999).

Research Questions

The following eight research questions were developed for the analysis of PSTs' conceptual understanding of the water cycle:

1. How do EPSTs' and SPSTs' conceptual understanding compare concerning the water cycle?
2. How do EPSTs' and SPSTs' conceptual understanding and confidence compare regarding the water cycle?
3. What is the relationship between EPSTs' and SPSTs' scores on the WCDT and their science scores' from the CBASE?

4. What is the relationship between the conceptual understanding of the water cycle held by those ESPTs and SPSTs who studied the water cycle as undergraduates and by those PSTs who last studied the water cycle during their K-12 education?
5. What is the relationship between the conceptual understanding of the water cycle held by those EPSTs and SPSTs who studied Earth Science as undergraduates and by those PSTs who last studied Earth Science during their K – 12 education?
6. What is the relationship between the conceptual understanding of the water cycle held by those EPSTs and SPSTs who have a higher interest in listening to and/or viewing weather-related media and by those PSTs who have a lower interest?
7. What is the relationship between the conceptual understanding of the water cycle held by those EPSTs and SPSTs who have experienced severe weather events and those PSTs who have not experienced severe weather events?
8. What are the common alternative conceptions about the water cycle held by EPSTs and SPSTs?

Conclusions of the Study

1. A valid, reliable three-tier diagnostic test was developed for assessing PSTs' conceptual understanding of the water cycle.
2. PSTs' prior knowledge about the water cycle played an integral part in relation to the PSTs' final score on the WCDT.
3. SPSTs had greater content knowledge about the water cycle, which resulted in greater confidence.

4. PSTs who recently studied the water cycle in an atmospheric science and/or meteorology course showed a greater understanding with confidence on the WCDT.
5. PSTs that had a higher frequency of using media for weather-related information had a better understanding of the water cycle.

Discussions

Researching PSTs' and teachers' alternative conceptions, Wandersee et al. (1994) claimed:

> Teachers often subscribe to the same alternative conceptions as their students… teachers hold a substantial array of alternative conceptions in the domain of natural sciences should not be particularly surprising, especially to teachers themselves, and is surely not news to those engaged in teacher education programs (p.189).

Therefore, the WCDT was developed to help science methods and content educators discover their PSTs' prior knowledge of the water cycle. This instrument allows diagnosing of a PSTs' knowledge and/or alternative conceptions of the water cycle. Subsequently, instructors can develop a plan for mitigating PSTs' misconceptions and improve their content knowledge regarding the water cycle.

Potential Alternative Conceptions

In order to determine if PSTs actually have alternative conceptions rather than a lack of knowledge of the water cycle, a third tier with a CRI index was added to the WCDT. The Cronbach alpha was 0.86 indicating a good internal consistency of the PSTs' answers for the third tier (Crocker & Algina, 2008). Several studies at this time have added a third tier to adjust for participants' guessing on items found on traditional two-tiered DTTs (Arslan, Cigdemoglu, & Moseley, 2012; Caleon & Subramaniam, 2010a; Odom & Barrow, 2007; Pesman & Eryilmaz, 2010). Caleon and Subramaniam (2010a) stated "…students tended to be poorly discriminating between what they know, and what they do not know, confidence ratings may reflect the strength of students' conceptual understanding, as well as their alternative conceptions" (p.941).

Table 53 illustrates the breakdown of the PSTs' correct responses by percent for each item on the WCDT's first two tiers as well as the overall percent of PSTs' correct responses for those tiers combined. Included within this table are the percentages for the PSTs' responses to the WCDT's confidence tier for each item. In order to determine if the PSTs had alternative conceptions or suffered from a lack of knowledge about a concept, potential alternative conceptions from Tables 51 and 52 were analyzed in conjunction with the PSTs' third-tier ratings. Potential alternative conceptions from Tables 51 and 52 were selected using the "10.0 % and higher" rule normally used by two-tiered assessments for individuals' incorrect responses (e.g., Chandrasegaran, Treagust, and Mocerino, 2007; Odom and Barrow, 1995; Wang, 2007).

Selection of "Guessing" or "Uncertain" on the WCDT will be considered as low confidence, and will be used as an indication of lack of knowledge even if the participant had a correct answer. Hasan et al. (1999) said in the following study, after they added a CRI to the FCI: "Irrespective of whether the answer was correct or wrong, a low CRI value indicates guessing, which, in turn, implies a lack of knowledge" (p. 295). In 2007, Odom and Barrow (2007) revised the DODT into a three-tiered test and stated that "…students who have low certainty in their answer combinations were possibly guessing; and, therefore had no understanding, or were confused about their understanding," (p. 97). Items that show PSTs answering both the first and second tiers correctly but having

Table 53

An Overview of PSTs' Tier Responses on the WCDT

		% Correct			Third Tier % "Low Confidence"		"High Confidence"	
Factor	WCDT Item	First Tier	Second Tier	Both First and Second Tiers	Guessing	Uncertain	Confident	Very Confident
Phase Change of Water	1	26.3	10.4	5.3	22.1	35.1	33.8	9.1
	2	16.9	42.9	11.7	26.0	33.8	29.9	10.4
	3	5.2	22.1	5.2	40.3	42.9	15.6	1.3
Condensation and Storage	4	76.6	79.2	74.0	5.2	18.5	39.0	36.4
	5	72.7	55.8	54.5	9.1	36.4	46.8	7.8
	6	88.3	88.3	88.3	15.6	27.3	39.0	18.2
Clouds	7	84.2	39.5	34.2	31.2	44.2	18.2	6.5
	8	53.2	15.6	14.3	10.4	41.6	40.3	7.8
Global Climate Change	9	81.8	79.2	74.0	13.0	23.4	49.4	14.3
	10	26.0	45.5	19.5	18.2	36.4	35.1	10.4
	11	14.3	14.3	14.3	6.5	18.2	48.1	27.3
Movement through the Water Cycle	12	88.2	30.3	27.6	16.9	29.9	40.3	13.0
	13	88.3	88.3	88.3	3.9	29.9	46.8	27.3
	14	54.5	46.8	45.5	16.9	36.4	36.4	10.4
	15	35.1	27.3	27.3	32.5	46.8	15.6	5.2

low confidence are considered to be a "lucky guess." This category was recently added to the CRI analysis for the AREPDiT (Arslan, Cigdemoglu, & Moseley, 2012).

Those PSTs who select "Certain" and/or "Very Confident" as their responses for the confidence tier of the WCCT will be considered as having high confidence. If this selection occurs with an incorrect response in either the first or second tier or both from a participant, then this will be an indication of what has been called a "tenacious misconception" by several studies (Arslan, Cigdemoglu, & Moseley, 2012; Caleon & Subramaniam, 2010a; Odom & Barrow, 2007). Selecting correct responses for both the first and second tiers will be considered as having the proper scientific knowledge for that specific topic.

Phase Change of Water

Item 1 deals with the process of deposition. Only 5.3 % of the PSTs answered both the first and second tiers correctly. Given that the majority (57.1 %) of PSTs indicated that they had low confidence on this item, PSTs are experiencing lack of content knowledge rather than an actual alternative conception about this process. Additionally, this conclusion can be seen with three incorrect selections both in the content and reason tiers having been selected by PSTs 10 % or greater. This means that the distractors for this item were viable responses for selection. This is the first study to analyze this particular topic.

Item 2 deals with the selection of the greenhouse gas that causes the greatest amount of heating in the atmosphere. PSTs had a low total score (11.7 %) with an overall low confidence rating (59.7 %). This indicated that many of the PSTs lack content knowledge about greenhouse gases, but one selection on the content tier, "Carbon dioxide," which was selected by 68.0 % of the PSTs, has been noted in a recent study (Arslan, Cigdemoglu, & Moseley, 2012) as being a misconception that has been linked to the media's fixation on the anthropogenic nature of carbon dioxide, and its relationship to global climate change.

Item 3 examined latent heat and its involvement with the phase changes of water. The combination of 5.2 % of the PSTs answering this question correctly, and 83.1 % of the PSTs expressing low confidence in their answers demonstrated that the PSTs lacked knowledge about this topic, which coincides with 40.3 % of the PSTs stating that they were "Guessing." Misconceptions about the phase changes of water have been documented by Henriques (2000), but misconceptions about latent heat were not mentioned by Henriques. PSTs also have limited knowledge of the transmission of heat energy by their selections of the three distractors found in the content tier.

Condensation and Storage

Item 4 examined the PSTs' knowledge of condensation. PSTs had both a high score (74.0 %) and a high confidence (75.3 %) for this item. The majority of the PSTs have the proper scientific knowledge on this topic, but there was one reason response that is considered a misconception by other studies (Ewings & Mills, 1994; Henriques, 2000; Osborn & Cosgrove, 1983). The selected response reflects individuals (children and undergraduates) believing that condensation occurs by water seeping through a container or by a glass sweating. None of the studies concentrated mainly on the water cycle.

Item 5 examined latent heat that is transferred within the atmosphere during the process of condensation. Scores showed that PSTs had a moderately high confidence rating (54.5 %) with 54.4 % selecting the correct answers for both tiers. Overall, the PSTs did not generate an alternative conception from the item. At this time, this research study is the first to examine this concept.

Item 6 revealed no alternative conceptions about water storage from the PSTs' answers. PSTs had a moderately high confidence (57.1 %) with 88.3 % of the PSTs correctly answering the question.

Clouds

Items 7 and 8 examined the concept of clouds and their development. Similar to item 6, item 7 generated a very high score (84.2 %) for the content tier, but only 39.5 % of the PSTs correctly selected the reason for the item, with an outcome of 34.2 % correct. The lower score also generated a low confidence (75.3 %) from the PSTs which shows that the PSTs were unsure of their reason for their first tier selection. This means the PSTs knew how basic cloud types are named, but lack the knowledge of the meaning of those basic cloud types' names. Henriques (2000) documented studies from other researchers on misconceptions about clouds, but none of them focused upon this topic.

Item 8 investigated PSTs' knowledge of phase change of water in clouds. Very few individuals got this item correct (14.3 %) and this corresponded with a low confidence rating (51.9 %). Therefore, PSTs had a lack of knowledge about this topic. Once again, no previous research has been conducted on this particular topic.

Global Climate Change

Items 9, 10, and 11 covered global climate change. Item 9 investigated the PSTs' knowledge of the causes of the flow within the water cycle system. PSTs had both a high confidence (63.6 %) and high percentage of individuals scoring correctly (74.0 %). There is a minimal concern about alternative conceptions generated by this item. No previous research studies have been conducted on this particular topic.

Item 10 dealt with greenhouses gases in the atmosphere. The PSTs had a low confidence at 54.5 % along with very few PSTs getting this item correct (19.5 %). Once again, PSTs selected “Carbon dioxide” as their answer to the content at 58.4 %. This verifies the alternative conception found in item 2 where PSTs did not recognize water vapor as a greenhouse gas. This relates to the findings of Arslan, Cigdemoglu, & Moseley (2012) about greenhouse gases and the media’s fixation on the anthropogenic nature of carbon dioxide, and its relationship to global climate change.

Item 11 examined melting of sea ice and conservation of matter as described by Bar (1989) in the study *Children’s Beliefs on Water Evaporation*. This was the only item on the WCDT that generated an extreme high confidence rating (75.3 %) from the PSTs with a low item score (14.3 %). Many PSTs thought they had selected the correct answer, but did not. Most of the PSTs stated that sea level would rise (84.4 %), and then selected “The extra water produced due to the melting will cause sea level to rise and flood coastal areas” as their reason (83.1 %). Both of these would be considered alternative conceptions of the PSTs. Stavy (1987) studied 5 to 10 year olds children’s’ observation of a melting ice cube and asked what happened to its mass when it melted; she found that as the children became older they realized that the mass was conserved. However, no other studies were found on adults’ perceptions of melting sea ice due to global warming.

Movement through the Water Cycle

This factor included items 12, 13, 14, and 15. Item 12 investigated the rate of evaporation when atmospheric temperature drops. A large majority of PSTs correctly selected the content tier's answer (88.2 %), but only 27.6 % selected the correct answer to both tiers. The confidence level was 53.2 %. This indicates that the PSTs have an alternative conception with the high confidence generated from a low score. The main problematic area was the reason selection of "Cooler air provides a lower amount of energy for evaporation." This is the first time this concept was analyzed by a researcher.

Item 13 dealt with sources of water storage within the water cycle. Similar to item 6, this item is also about water storage, and revealed no alternative conceptions from the PSTs' answers. PSTs had a high confidence (74.0 %) with 88.3 % of the PSTs correctly answering the question. For both of these items, the topic of water storage within the water cycle has not been previously studied.

Item 14 investigated the total volume of water within the water cycle. It was found that the PSTs had a lack of knowledge of this topic due to their low score (45.5 %) and low confidence rating (46.7 %). Item 15 explored the PSTs' understanding of cloud formation. PSTs' responses indicated they lack the knowledge to correctly answer this question due to low confidence (79.2 %) and low score (27.3 %). Previous research studies have explored neither of those topics.

With the addition of the confidence tier to the WCDT, many potential alternative conceptions (Tables 51 and 52) that would have been recognized by developers of two-tiered diagnostic tests have been eliminated and found to be caused by the PSTs' lack of knowledge. This relates highly to the PSTs' overall score on the WCDT's first two tiers of 38.9 %, and the length of time since they last studied the water cycle. The SPSTs were more likely to have studied the water recently than the ESPTs. This was evident when analyzing those results, $t\ (75) = -3.94$, $\rho = 0.0002$, using an independent two-tailed t-Test.

In addition, SPSTs were more likely to have had a chance to study the water cycle in an Earth Science course recently than ESPTs, $t\ (75) = -2.11$, $\rho = 0.038$.

Implications

An overarching question asked at the beginning of this study was **"**do our future teachers have sufficient understanding of water and the water cycle to reach the necessary achievement level for scientific literacy?" Examination of the data shows a resounding, "No" for the participants with the ESPTs' averaging 33.5 % and the SPSTs a 43.9 % on the WCDT. The question then becomes "why do the PSTs lack an understanding of the water cycle?" The analyzed data reveals an answer to that question, too. The PSTs lack of content knowledge, along with the diagnosed alternative conceptions about the water cycle could potentially be transferred to the PSTs' future students.

Lack of content knowledge was evident especially from the analysis of the EPTs' score with five additional alternative conceptions that were not found from the SPSTS' scores but according to Abell, Appleton, & Hanuscin (2010) requiring ESPTs to take more science courses in order to gain additional content knowledge about a topic was not an effective learning strategy for ESPTs. Schoon and Boone (1999) found that having ESPTs enroll in science courses designed especially for them was a more effective way for ESPTs to learn the content. With the new *NGSS*, universities will need to reexamine their science courses required for ESPTs and established courses that cover the three main disciplinary core areas: Life, Physical, and Earth and Space Sciences.

Recommendations for Future Studies

A goal for future studies would be to examine PSTs from other institutions about their PSTs' understanding of the water cycle using the WCDT and demographic survey.

Besides expanding the size of the sample, which more than likely would raise the reliability coefficient for the WCDT; this also could make the WCDT a more inclusive instrument of water cycle processes.

Second, the WCDT should be given in conjunction with a developed intervention intended for improving individuals' conceptual understanding of the water cycle in a pre-test and post-test situation. Allowing the WCDT to be given as pre-test/posttest, researchers could perform a confirmatory factor analysis which would check the WCDT for construct consistency.

Third, researchers could used the WCDT in conjunction with the developed rubric (Schaffer & Barrow, 2011), used for grading the PSTs' water cycle representations in this study, to examine if there is still a relationship between an individuals' score on the WCDT and the score they receive from the drawing the water cycle. Many research studies (Ben-zvi-Assarf and Orion, 2005; Cardak, 2009; Morrell and Schepia, 2009; Shepardson et al., 2009) on the water cycle have had their participants draw water cycle representations, but none used a rubric to evaluate those drawings. They used ground theory to find patterns within the drawing and had to interview participants to make generalizations.

Fourth, researchers need to explore non-majors' understanding of the water cycle using the WCDT and demographic survey to examine if they have a similar level of understanding about the water cycle, weather-related experiences, and alternative conceptions that were generated by PSTs.

Fifth, researchers could analyze the use of an online implementation of the WCDT. This would allow investigators to retrieve participants' answers quickly for evaluation. In addition, this could include breaking the items on the WCDT into sections by factor and/or content areas. Using this type of implementation would allow the use of clickers by instructors.

Sixth, items on the WCDT could be turned into individual probes for participants' understanding of different processes found in the water cycle. These probes could be used during the class, and then those items could be used in a summative assessment format by the instructor. Analysis would examine if the individual probes had any effect on participants' score on the summative assessment.

Seventh, researchers could use the WCDT and demographic study in conjunction with a professional development program for in-service teachers. By administering the WCDT as a pre- and posttest, the professional development providers could analyze teachers' gain scores to examine instructional quality of the program.

Eighth, the AMS could use the WCDT as a tool for revising curriculum used for their educational programs that focus on pre-college teacher training in the atmospheric, oceanographic, and hydrologic sciences.

Ninth, the WCDT could add an additional fourth tier that would examine the students' confidence of tiers one and two separately. This addition would allow researchers to further examine if students possess truly the alternative conceptions found using the three-tiered structure or just have a lack of knowledge about the water cycle. Using this type of analysis, a new level of 20.0 % for incorrect answers would be used. Currently, there is only one research study that is using a four-tiered structure (Caleon & Subramanian, 2010b).

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APPENDIX A

COVER AND PERMISSION LETTER

University of Missouri-Columbia

D. L. Schaffer
Science Education
Graduate Research Assistant
MU Science Education Center
303 Townsend Hall, Suite 321-O
Columbia, Missouri 65211
dlszh3@mail.missouri.edu

To: Pre-service Elementary Education and Secondary Science Teachers

The Missouri University Science Education Center is interested in pre-service teachers' knowledge about the water cycle, and the factors that may contribute to that understanding. We, Dr. Lloyd Barrow and I, invite you to participate in my dissertation study entitled "The Development and Validation of a Three-Tier Diagnostic Test Measuring Pre-service Elementary Education and Secondary Science Teachers' Understanding of the Water Cycle." This study's findings could be used to improve the effectiveness of K-12 teacher preparation in the Earth Sciences. In addition, it could assist in today's reform movement in science education.

Your participation in this study is voluntary. Your refusal to participate will involve no impact upon your grades that you receive from this science methods class. If you wish, you may discontinue participation at any time. In addition to your responses from the water cycle assessment and survey, you will be giving the researcher permission to collect your CBASE science content score from the College of Education. After analysis of the data collected, I will be randomly selecting eight individuals to participate in an interview discussing their understanding of the water cycle. Individuals completing the interview portion of the study will receive a $25.00 Wal-Mart gift card.

Any information that is obtained in connection with this study and that can be individually identified with you will remain confidential. Assessment responses, CBASE test scores, survey responses, and interviews with be kept in a confidential file that will remain locked in my office. Only Dane Schaffer will have access to this data. Data analysis will only be conducted on groups, not individuals.

If you agree to participate in the study, please sign on the next page, and then complete all questions on the attached assessment and survey. Also, please indicate if you would be willing to be part of the interview potion of this study. There are no risks or discomforts associated with this research.

The researchers can be contacted for further questions about the research. See contact information for researchers at the bottom of the page. Additional questions regarding your rights as a research participant should be addressed to: Institutional Review Board, University of Missouri, 483 McReynolds Hall, Columbia, MO 65211; telephone 573-882-9585.

Sincerely,

Dane L. Schaffer
Graduate Research Assistant
303 Townsend Hall, Suite 321-O
Columbia, MO 65211
dlszh3@mail.missouri.edu

Lloyd H. Barrow
Professor of Science Education
303 Townsend Hall
Columbia, MO 65211
BarrowL@missouri.edu

Please print name legibly, then sign below and date, if you wish to participate in the study.

I, ______________________________, willingly participate in this science education research study. My signature below is voluntary provided.

I am interested in participating in the interviews:
(Please Check One): Yes ☐ No ☐

Signature: ______________________________

Date: ______________

APPENDIX B

THE WCDT with ANSWER SHEET

THE WCDT

Directions: DO NOT WRITE ON THIS ASSESSMENT. Place all your answers on the attached answer sheet.

1. On a beautiful morning in late November, you go outside and all of the windows on your car are covered with frost. Why did this frost form?
   a. Condensation
   b. Deposition
   c. Temperature change
   d. Sublimation

   The reason for your selection is because:
   a. The air temperature falls below 32˚F/0˚C.
   b. Happens when water vapor changes into ice, and the temperature is below 32˚F/0˚C.
   c. A direct change from a gas to a solid regardless of temperature.
   d. Happens when water changes to ice near the earth’s surface and the temperature is near or below 32˚F/0˚C.

2. What is the most prevalent greenhouse gas found in the atmosphere?
   a. Carbon dioxide
   b. Methane
   c. Water vapor
   d. All of the above have the same concentration in the atmosphere.

   The reason for your selection is because:
   a. Through the processes of excretion and respiration by animals.
   b. Through the process of transpiration of plants.
   c. Varies with the season and time of day.
   d. Most abundant gas found in the atmosphere.

3. Latent heating of the atmosphere refers to heat transferring through the process of:
   a. Conduction
   b. Convection
   c. Radiation
   d. Phase changes of water

   The reason for your selection is because:
   a. Changing from a solid to liquid to a gas provides heating for the water cycle.
   b. The sun’s energy provides heating for the atmosphere.
   c. There is no transfer of energy when water molecules change to water vapor.
   d. When water particles come into contact with one another and transfer energy.

4. On a hot summer day, you get a cold beverage from the refrigerator. You put the can down on a table, and a little while later you return and notice a puddle of water has formed around the outside of the can. Where did this water come from?
    a. From the ice melting inside the can
    b. From the beverage and ice melting from the can
    c. From the beverage and ice condensing inside the can
    d. From the air outside the beverage

   The reason for your selection is because:
    a. Warming of beverage caused the beverage to expand and spill out of the can.
    b. Ice on the outside of the beverage melted and created the puddle.
    c. The beverage warmed and caused water to condensate inside the can, and the extra water caused too much volume in the can and seeped out.
    d. Water vapor from the atmosphere cooled and condensed when coming into contact with the cold beverage.

5. Condensation happens when water vapor rises into the atmosphere and:
    a. Cools
    b. Warms

   The reason for your selection is because:
    a. Condensation is a cooling process like low humidity on a warm summer day.
    b. Condensation is a warming process like high humidity on a warm summer day.
    c. Water cools to its saturation point and condensation occurs.
    d. Water warms to its vaporization point and condensation occurs.

6. Which of the following is the major source of moisture that reaches or becomes part of Earth's atmosphere?
    a. Lakes
    b. Rivers
    c. Polar caps
    d. Oceans

   The reason for your selection is because:
    a. When compared to other water sources, the oceans cover over 70% of the earth's surface.
    b. Lakes are shallower than oceans, and water can evaporate more quickly from their surfaces into the atmosphere.
    c. The rapid movement of water in the world's river systems causes moisture to be transported from the earth's surface to the atmosphere at a greater rate than lakes and the oceans.
    d. Polar ice caps and glaciers contain fresh water which is easily transferred to the earth's atmosphere.

7. Basic cloud types are named upon:
    a. Form.
    b. Height.
    c. Both form and height.

   The reason for your selection is because:
    a. Cirrus clouds are wispy that form high in the atmosphere and are compose of ice crystals.
    b. When a cloud name starts with "alto-" it means low in atmosphere.
    c. Cumulus clouds form horizontally to the earth's surface.
    d. Stratus clouds usually cause precipitation.

8. Water in clouds may change from liquid to solid:
    a. Only at 32˚F/0˚C.
    b. At 32˚F/0˚C and temperatures below 32˚F/0˚C.
    c. At temperatures above 32˚F/0˚C.
    d. Water in clouds never freezes.

   The reason for your selection is because:
    a. Water vapor does not freeze in clouds.
    b. Water droplets cool while falling to earth, and change into ice.
    c. Clouds can have supercooled water in them.
    d. Water vapor goes directly to a solid without forming a liquid.

9. The flow of water in the water cycle is caused by:
    a. The heat from the sun
    b. The gravitational attraction of the earth
    c. The gravitational attraction from the moon
    d. Both a and b

   The reason for your selection is because:
    a. Any movement on earth is controlled by its' own gravitational forces.
    b. The energy of the sun causes water vapor to evaporate into the atmosphere, and earth's gravity pulls water back to earth during precipitation.
    c. Both the ocean's tides and the moon drive the flow of the water cycle.
    d. Only the sun completely controls the movement of water on earth.

10. Which of the following greenhouse gases can cause an increase in the temperature of the atmosphere?
    a. Carbon dioxide
    b. Water Vapor
    c. Ozone
    d. Both a and b

The reason for your selection is because:
    a. Increases in global population produce more of this gas.
    b. Can vary depending on the season.
    c. Gas can hold heat within the atmosphere.
    d. Allows more sunlight to reach the earth's atmosphere.

11. The melting of floating sea ice due to global warming will probably cause:
    a. Sea level to rise
    b. Sea level to fall
    c. No change in current sea levels

The reason for your selection is because:
    a. The extra water produced due to the melting will cause sea level to rise and flood coastal areas.
    b. The loss of the sea ice will lower sea level because ice weighs more than water.
    c. No change in sea level will happen because sea ice and water have the same volume.

12. When the temperature of water and the atmosphere becomes colder, the rate of evaporation:
    a. Decreases
    b. Increases
    c. Stays the same

The reason for your selection is because:
    a. Cooler air provides a lower amount of energy for evaporation.
    b. Cooler air provides a greater amount of energy for evaporation.
    c. Rate of evaporation is not influenced by temperature.
    d. Air's capacity to hold water vapor is a function of temperature.

13. Most of the water on earth is found in:
    a. Glaciers and ice caps
    b. Large lakes and streams
    c. Underground water
    d. Oceans

    The reason for your selection is because:
    a. Greatest volume and depth of water on earth.
    b. Vast amounts of water lay underneath the earth's surface.
    c. Frozen water stored in Polar Regions and at higher attitudes.
    d. Runoff collects fresh water sources.

14. The total volume of water on earth is:
    a. Almost constant
    b. Decreasing
    c. Increasing
    d. Varies over time

    The reason for your selection is because:
    a. Water cycle is a closed system, so no water is lost or gained.
    b. Water cycle is an open system so the total volume of water constantly changes either up or down.
    c. Water cycle is an open system that allows water to escape into the earth's interior.
    d. Water cycle is an open system that allows water vapor from space to enter our atmosphere, and eventually fall to earth.

15. What is needed for clouds to develop?
    a. Water vapor and atmospheric dust
    b. Ozone, water vapor, and nitrogen
    c. Low pressure with low relative humidity
    d. Oxygen and hydrogen

    The reason for your selection is because:
    a. Essential elements needed to form water.
    b. Dust allows water droplets to come together.
    c. Influenced by a variety of atmospheric gases in order to form.
    d. Atmospheric conditions needed for cloud formation

Name ____________________________

Water Cycle Answer Sheet

This content assessment consists of a series of three different selections for each question. Each question has content, a reason for your content selection, and a level of confidence to answers. Record your three responses that you feel best reflect your understanding for each question. We are also asking how confident you are with the answers you selected using the rating scale below. Please place a number that reflects your confidence level for your content and reasoning selection. For the demographic survey, please check-mark the answer to the question that best reflects you.

How confident are you?

1. Guessing 2. Uncertain 3. Confident 4. Very confident

AN EXAMPLE: A balloon sticks to a wall after being rubbed on a sweater because of

a. Chemical energy
b. Magnetism
c. Mechanical energy
d. Static electricity

The reason for your selection is:

a. The rubbing causes the protons in the balloon to be polarized.
b. The rubbing causes a transfer of elements from the sweater to the balloon.
c. The rubbing causes work to be performed on the balloon.
d. The rubbing causes the surface of the balloon to have an unbalance amount of electrons.

Answer D Reason D Confidence Rating 3

1. Answer ______ Reason ______ Confidence Rating ______
2. Answer ______ Reason ______ Confidence Rating ______
3. Answer ______ Reason ______ Confidence Rating ______
4. Answer ______ Reason ______ Confidence Rating ______
5. Answer ______ Reason ______ Confidence Rating ______
6. Answer ______ Reason ______ Confidence Rating ______
7. Answer ______ Reason ______ Confidence Rating ______

8. Answer _______ Reason _______ Confidence Rating _______

9. Answer _______ Reason _______ Confidence Rating _______

10. Answer _______ Reason _______ Confidence Rating _______

11. Answer _______ Reason _______ Confidence Rating _______

12. Answer _______ Reason _______ Confidence Rating _______

13. Answer _______ Reason _______ Confidence Rating _______

14. Answer _______ Reason _______ Confidence Rating _______

15. Answer _______ Reason _______ Confidence Rating _______

APPENDIX C

DEMOGRAPHIC SURVEY

Demographic Survey

Directions: For the demographic survey, please check-mark the answer to the question that best reflects you and your experiences.

1. When was the last time you studied the water cycle? (Check only one)

   Elementary School ☐
   Middle School ☐
   Jr. High School ☐
   High School ☐
   College ☐

2. Have you completed atmospheric science/meteorology class as an undergraduate?

   Yes ☐ No ☐

3. When was the last time you had an Earth Science class? (Check only one)

   Elementary School ☐
   Middle School ☐
   Jr. High School ☐
   High School ☐
   Community College ☐

4. How often do you use the following media sources for obtaining news about the weather?

	Never	Rarely	Sometimes	Often
Local Radio	☐	☐	☐	☐
Local Television	☐	☐	☐	☐
The Weather Channel-TV	☐	☐	☐	☐
The Weather Channel-Web	☐	☐	☐	☐
NOAA Weather Radio	☐	☐	☐	☐
Cell phone–Weather Alert	☐	☐	☐	☐
Internet	☐	☐	☐	☐
Social Media Sources	☐	☐	☐	☐

5. Which of the following have you experienced?
(Check all that apply)

Tornado	□
Hurricane	□
Flooding	□
Hail (>2 inches in diameter)	□
Blizzard	□
Snow Avalanche	□
Struck by Lightning (Home, you and/or family member)	□
Mudslides caused by excessive rains	□
Prolonged Drought (>3 months)	□

6. Male □ Female □

APPENDIX D

LOGISTIC REGRESSION ANALYSIS FOR ITEM BIAS

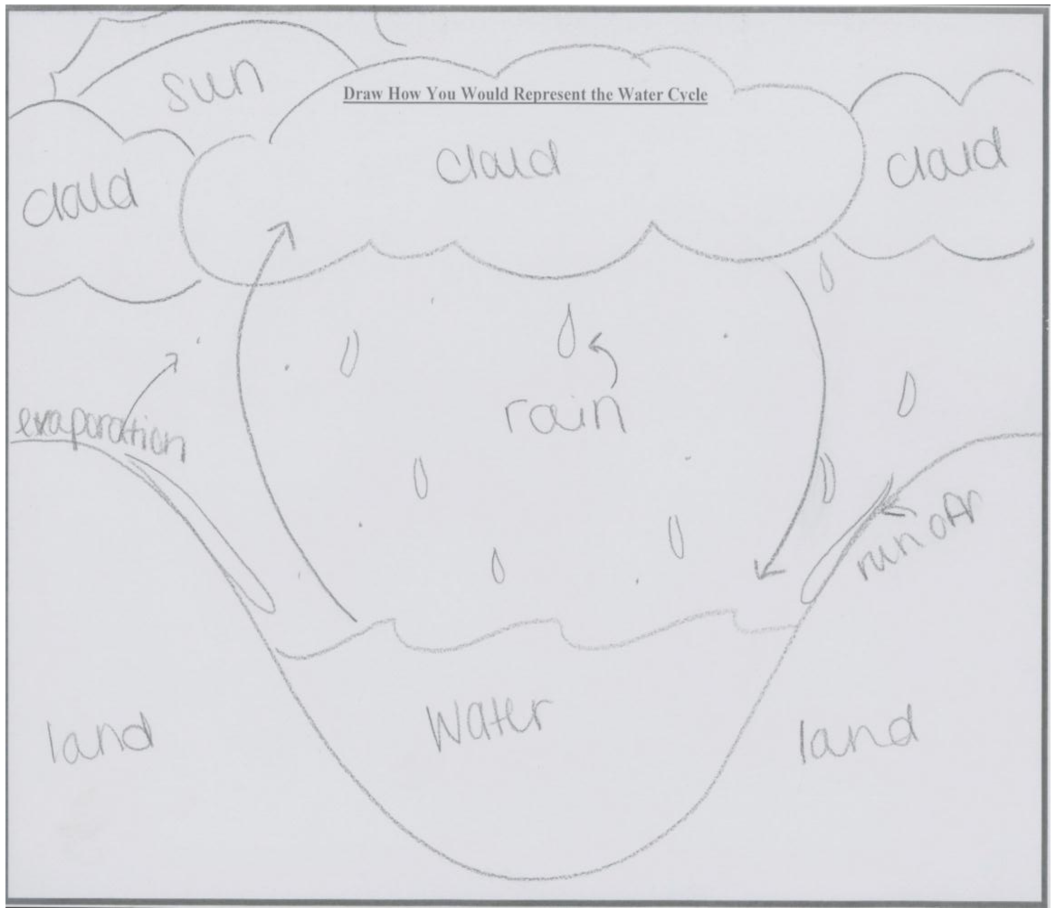
Logistic Regression for Item Bias

	Logistic Regression		
Item	Score	Group	Score x Group
Question 1	11.876**	0.745	0.234
Question 2	15.284**	1.537	1.723
Question 3	3.246	0.073	2.005
Question 4	12.790**	0.362	0.021
Question 5	0.589	0.207	0.000
Question 6	8.346**	0.804	0.959
Question 7	2.209	0.772	3.521
Question 8	7.381**	0.192	0.029
Question 9	20.033**	0.228	0.080
Question 10	1.634	0.898	2.336
Question 11	3.607	0.467	0.789
Question 12	3.752	2.813	0.581
Question 13	1.111	0.195	1.072
Question 14	20.399**	0.490	0.445
Question 15	3.009	1.564	0.000
Question 16	10.001**	0.507	0.723
Question 17	4.665*	0.003	0.718
Question 18	5.332*	0.100	0.699
Question 19	10.927**	0.678	0.745
Question 20	0.790	0.379	1.467
Question 21	4.479*	3.533	0.000
Question 22	2.258	0.953	0.420
Question 23	0.312	0.163	0.703
Question 24	7.321**	0.018	2.363
Question 25	1.315	1.282	9.111**
Question 26	1.465	0.770	0.000
Question 27	9.458**	0.440	0.363
Question 28	0.285	1.579	0.000
Question 29	4.463*	2.211	0.316
Question 30	3.775	2.979	0.316
Question 31	4.747*	0.431	0.765
Question 32	0.526	1.625	0.609

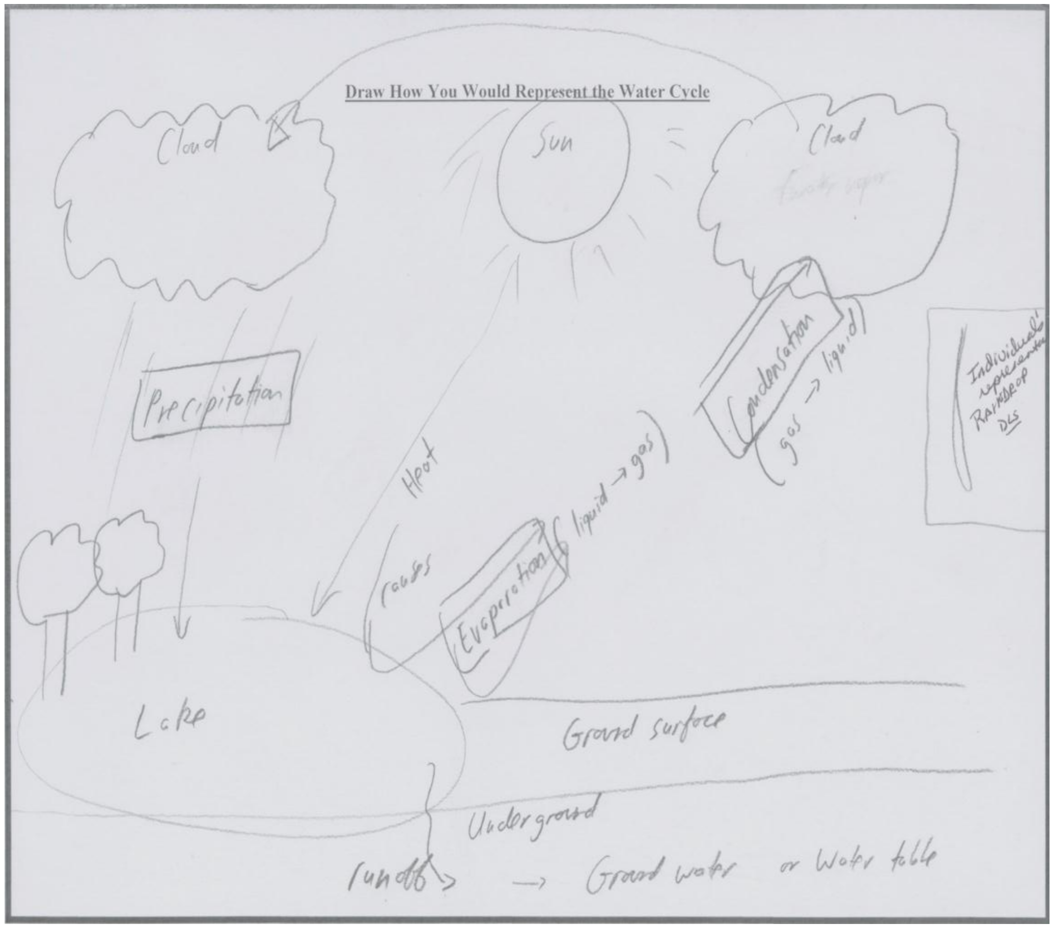
*$\rho < 0.05$, **$\rho < 0.01$

APPENDIX E

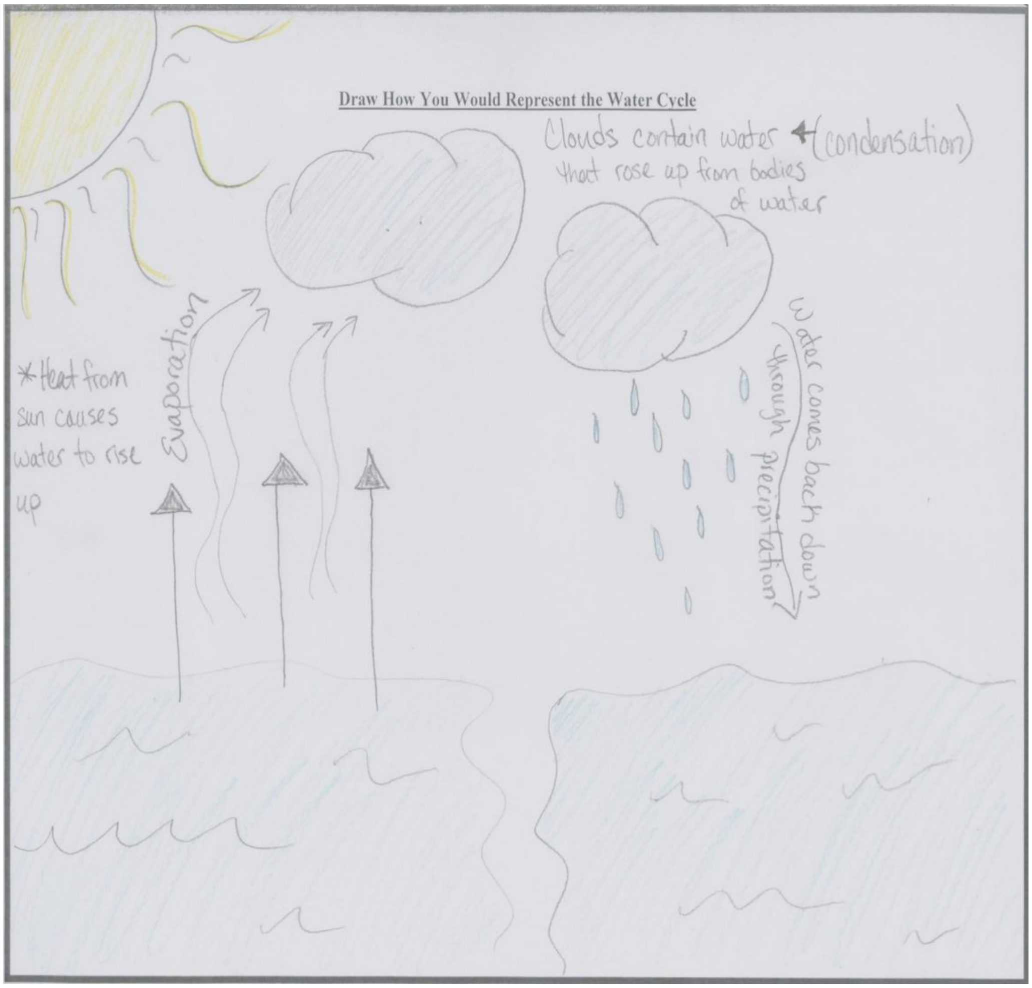
INTERVIEWEES' DRAWINGS OF THE WATER CYCLE



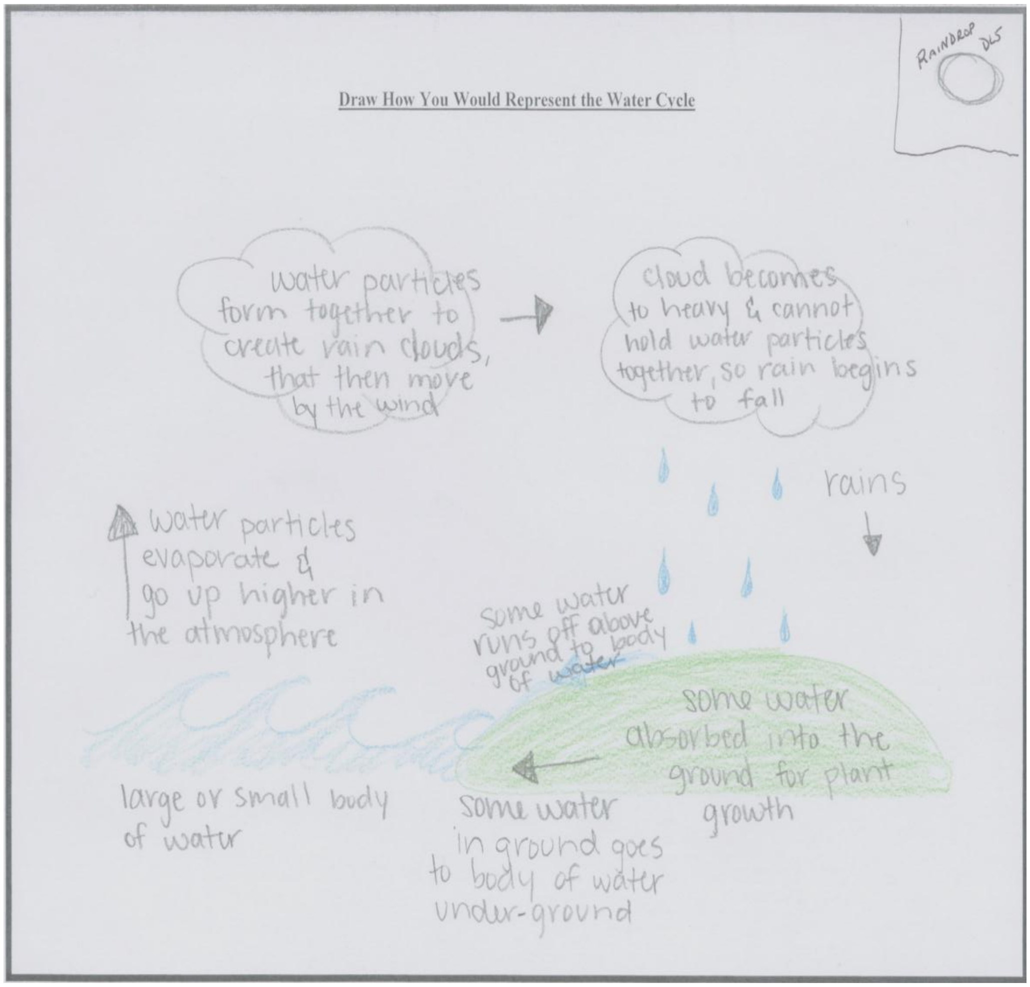
Drawing from Elementary PST – High Score and High Confidence



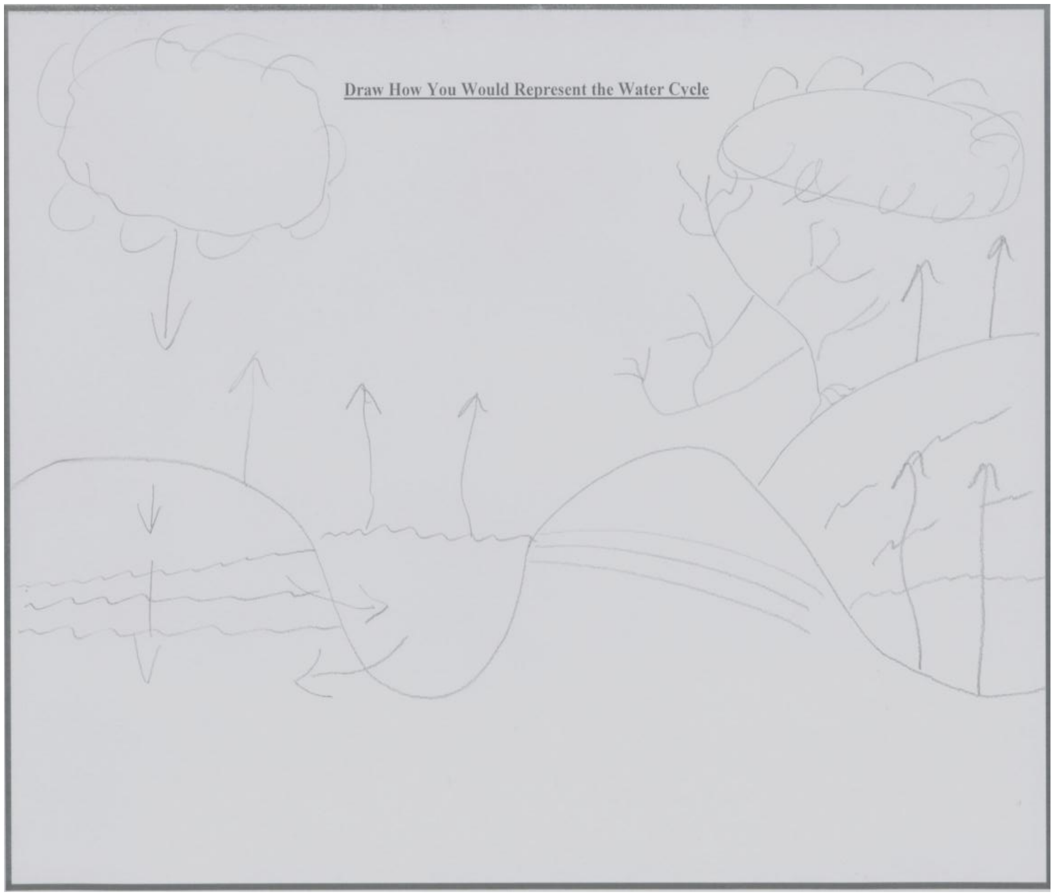
Drawing from Secondary PST – High Score and High Confidence



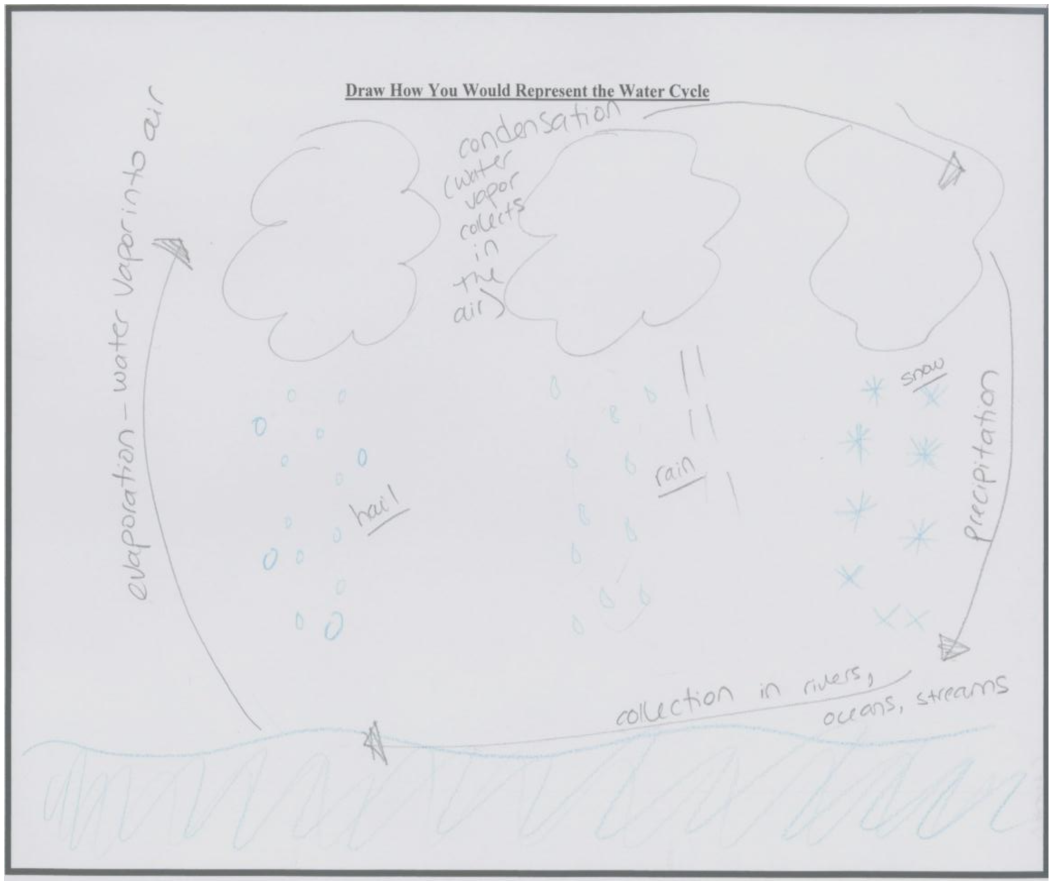
Drawing from Elementary PST – Low Score and High Confidence



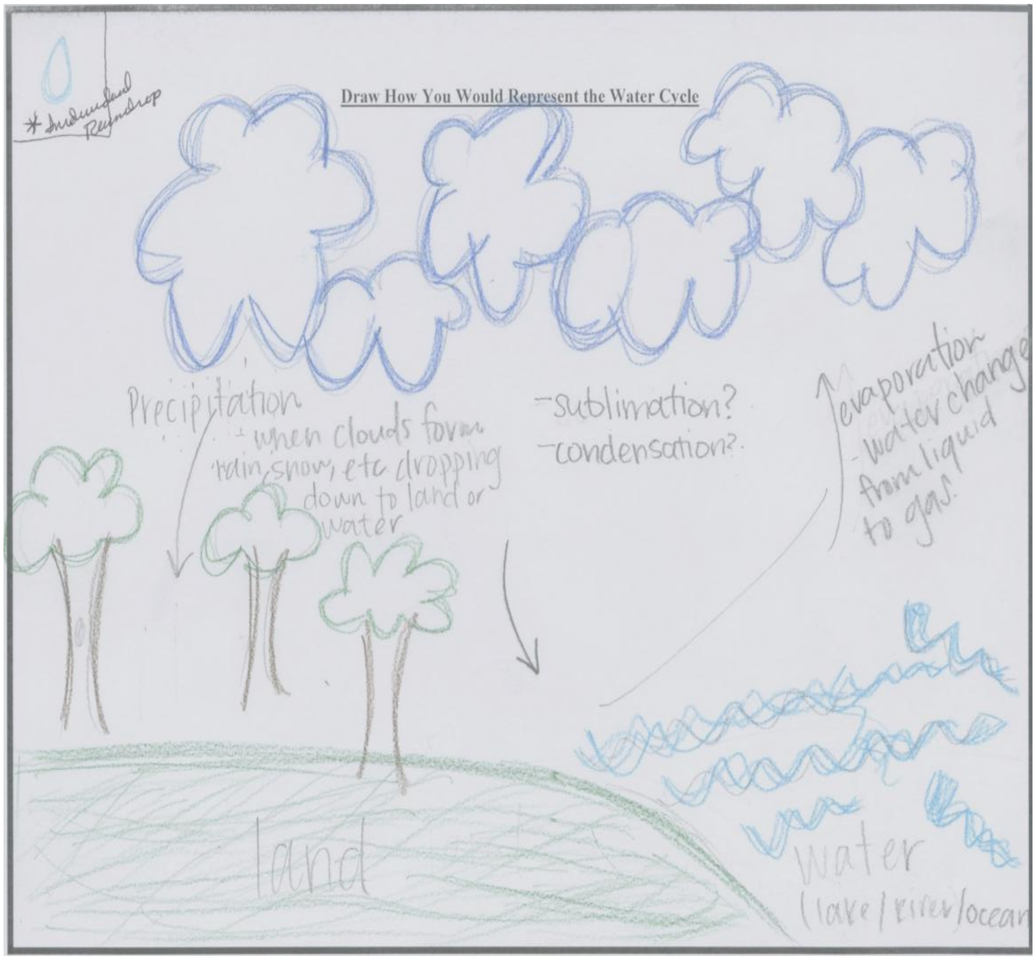
Drawing from Secondary PST – Low Score and High Confidence



Drawing from Secondary PST – High Score and Low Confidence



Drawing from Elementary PST – Low Score and Low Confidence



Drawing from Secondary PST – Low Score and Low Confidence

VITA

Dannah Lynn Schaffer was born on September 19, 1959 to Adriel and Vivian Schaffer in Evansville, IN, and grew up in Mt. Vernon, IN. After graduating high school in 1977, she attended Purdue University in West Lafayette, IN. In 1981, Dannah received a B.PE in Physical Education with a minor in General Science, and endorsements in athletic training and coaching. She stayed on at Purdue as a residence hall counselor and continued her studies as a post-baccalaureate student.

In 1982, Dannah started her teaching career in her hometown at Mount Vernon Junior High and Hedges Central Elementary. From 1985 - 1989, she taught science for grades 5 – 8, and 7th grade at Evansville Lutheran School. In 1990, Dannah completed her M. Ed with an emphasis in Science Education at Indiana State University in Terre Haute, IN. In 1990, she was a volunteer graduate instructor for athlete training at the University of Evansville. In 1992, Dannah was contracted substitute teacher in Mount Vernon before moving to teach in Kansas City, Missouri in 1993. While teaching Earth and Physical Science at Westport Business/Technology Communications Magnet High School, Dannah became a lead teacher in science for that school district, and worked on the districts' core curriculum team and textbook adoption committee, as well as representing the school district on the state's science assessment program. Later, she transferred to teach at East Agricultural and Environmental Magnet High School where she continued to work for the Kansas City School District.

In 1998, Dannah moved to take a position teaching the Advance Earth Sciences and Physical Science at McCluer North High School in Florissant, Missouri. While at

McCluer North, she worked on many district committees pertaining to the improvement of science education for K-12 students, and on several state committees that implemented Physical First as a ninth grade science. After over 20 years of teaching and coaching, Dannah left to pursue her life-long goal of obtaining a doctorate in science education. In the fall of 2008, she became a full-time doctoral student at the University of Missouri in Columbia.

While at the MU, Dannah has given numerous presentations and workshops pertaining to her research at state, national, and international conferences. She has worked as a teacher/supervisor for MU's SMAR^{2}T Program, a seminar instructor for undergraduates in secondary science, taught elementary science methods, advised graduate students' research projects, developed professional development workshops for teachers, and has worked as a research assistant on two NSF grants.

In 2010, she was awarded the Outstanding Graduate Teaching Assistant by the MU Science Education Center. Her goal after graduating in May of 2013 with her PhD is to find a position at an institution and/or agency that emphasizes improving Earth Science literacy.