THE IMPACT OF DISCOVERY LEARNING ON MIDDLE GRADE STUDENTS’
CONCEPTIONS OF THE WATER CYCLE

A Dissertation
Submitted to
the Temple University Graduate Board

in Partial Fulfillment
of the Requirements for the Degree
DOCTOR OF EDUCATION

by
John D. Yoder Jr.
August 2014

Sponsoring Committee Members:
Joseph DuCette, Psychological Studies in Education
Michael Smith, Curriculum, Instruction and Technology in Education
Catherine Schifter, Psychological Studies in Education
Doug Lombardi, Teaching and Learning in Education
ABSTRACT

This study examined the use of discovery learning in science and how it affects students’ academic performance as well as their self-efficacy in science. It also used a diagnostic tool to identify students’ misconceptions about processes in the water cycle and where the misconceptions originated. While the study showed that the treatment group had a statistically significant greater academic gain from the pre-test to the post-test than did the no-treatment comparison group, from a teachers view point the gain would not be enough to benefit a student’s performance on high stakes tests. Because the study was able to identify eight common misconceptions, it suggests that the misconceptions that students possess are difficult to uproot even using teaching methods that have been proven successful.
ACKNOWLEDGEMENTS

I would like to send my deepest appreciation to my committee chair and advisor, Dr. Joseph DuCette, who agreed to take me on as an advisee in the middle of the dissertation process. Without him I would have been a lost soul. I thank him for all his input and advice during the writing process and his gracious help with all the statistical background for my research.

I would also like to thank my other committee members Dr. Michael Smith, who helped me with my writing style and helped me to express myself on paper, Dr. Catherine Schifter, who helped me refine my writing and my study structure, and Dr. Doug Lombardi, who helped me tailor my vision and direction of my study. I have to also thank the late Dr. Joseph Schmuckler. His guidance and flexibility allowed me to create a good foundation on which to build this research.

In addition I would like to thank Dr. Rajul Pandya for starting me on this journey about misconception. Without his insight and guidance I may have never had the spark to start this journey.

Last but not least I have to thank my loving wife Stacey Yoder. If it were not for her I may have never finished. Her constant encouragement and coaching gave me the inspiration to complete this task even in the face of adversity.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>i</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>ii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>iii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>iv</td>
</tr>
</tbody>
</table>

## CHAPTER

1. INTRODUCTION
   - Statement of the Nature of the Problem                               | 1    |
   - Specific Research Questions                                          | 2    |
   - Definition of Terms                                                  | 3    |

2. REVIEW OF LITERATURE
   - Misconceptions in Science                                           | 6    |
   - Overcoming Misconceptions                                            | 11   |
   - Discovery Learning                                                    | 16   |
   - Self-efficacy                                                        | 22   |
   - Summary of Literature                                               | 25   |

3. METHODOLOGY
   - Sample                                                             | 27   |
   - Science Self-efficacy Survey                                        | 23   |
   - Misconceptions and Academic Performance                           | 29   |
   - Data Collection Tool                                               | 30   |
Treatment........................................................................................................... 40
Role of the Researcher........................................................................................... 45

4. RESULTS.......................................................................................................... 46
Sample.................................................................................................................... 46
Research Question 1................................................................................................ 47
Research Question 2............................................................................................... 50
Further Analysis by Academic Level.................................................................... 54
Research Question 3............................................................................................... 59
Research Question 4............................................................................................... 75
Summary of Results............................................................................................... 83

5. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS................................. 83
Summary.................................................................................................................... 83
Discussion of Conclusions..................................................................................... 85
Recommendations.................................................................................................... 97
Researcher’s Final Thoughts and Recommendations............................................ 100

BIBILIOGRAPHY.................................................................................................... 101

APPENDICES
A. PERMISSION TO USE DATA AND STUDENT ASSENT FROM...................... 112
B. SELF-EFFICACY SURVEY................................................................................. 116
C. MISCONCEPTION IDENTIFICATION TOOL..................................................... 117
D. STUDENT LEARNING AND UNDERSTANDING GUIDE................................. 119
E. NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION’S
DIAGRAM OF THE WATER CYCLE..................................................................... 120
F. DEFINITION SHEETS

G. RELATIVE HUMIDITY AND DEW POINT CHARTS

H. PROJECT DESCRIPTION FOR THE WATER CYCLE: PATH 1
   INDIVIDUAL STORY; PATH 2 GROUP PLAY; PATH 3 GROUP OR
   INDIVIDUAL VIDEO/POD CAST

I. PROJECT DESCRIPTION FOR THE WATER CYCLE: PATH 4

J. DAILY JOURNAL DURING THE STUDY
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1.  Table of Means and (Standard Deviations) for Correct Answers</td>
<td>49</td>
</tr>
<tr>
<td>4.2.  Repeated Measures ANOVA Results for Correct Answers</td>
<td>49</td>
</tr>
<tr>
<td>4.3.  Table of Means and (Standard Deviations) for Self-Efficacy</td>
<td>51</td>
</tr>
<tr>
<td>4.4.  Repeated Measures ANOVA Results for Self-Efficacy</td>
<td>51</td>
</tr>
<tr>
<td>4.5.  Table of Means and (Standard Deviations) for Confidence Ratings</td>
<td>52</td>
</tr>
<tr>
<td>4.6.  Repeated Measures ANOVA Results for Confidence Ratings</td>
<td>53</td>
</tr>
<tr>
<td>4.7.  Table of Means for Correct Answers</td>
<td>55</td>
</tr>
<tr>
<td>4.8.  Repeated Measures ANOVA Results for Correct Answers</td>
<td>55</td>
</tr>
<tr>
<td>4.9.  Table of Means for Correct Answers</td>
<td>57</td>
</tr>
<tr>
<td>4.10. Repeated Measures ANOVA Results for Correct Answers</td>
<td>57</td>
</tr>
<tr>
<td>4.11. Table of Means and (Standard Deviations) for Self-efficacy</td>
<td>58</td>
</tr>
<tr>
<td>4.12. Repeated Measures ANOVA Results for Self-efficacy</td>
<td>59</td>
</tr>
<tr>
<td>4.13. Item Breakdown for confidence rating pre &amp; post-test</td>
<td>61</td>
</tr>
<tr>
<td>4.14. EXP Item Breakdown for CR Pre &amp; Post</td>
<td>66</td>
</tr>
<tr>
<td>4.15. Correlations between Correctness and Confidence</td>
<td>73</td>
</tr>
<tr>
<td>4.16. Correlations between Correctness and Confidence- Post-Test only for Treatment and Comparison Groups</td>
<td>74</td>
</tr>
<tr>
<td>4.17. Tally of Reported Source Learning Areas for Individual Items Pre-test</td>
<td>76</td>
</tr>
<tr>
<td>4.18. Tally of Reported Source Learning Areas for Individual Items on Post-test</td>
<td>78</td>
</tr>
<tr>
<td>4.19. Tally of Reported Source Learning Areas for Individual Items on Post-post-test</td>
<td>81</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1. Plot of Interaction for Pre to Post Correct Answers</td>
<td>50</td>
</tr>
<tr>
<td>4.2. Plot of Pre-Post Confidence Ratings</td>
<td>53</td>
</tr>
<tr>
<td>4.3. Plot of Interaction for Pre to Post Correct Answers by Academic level</td>
<td>56</td>
</tr>
<tr>
<td>4.4. Plot of Interaction for Pre to Post-post Correct Answers by Academic level</td>
<td>58</td>
</tr>
<tr>
<td>4.5. Graph for Item 1 Pre-test All</td>
<td>62</td>
</tr>
<tr>
<td>4.6. Graph for Item 1 Post-test All</td>
<td>63</td>
</tr>
<tr>
<td>4.7. Graph for Item 3 Post-test All</td>
<td>64</td>
</tr>
<tr>
<td>4.8. Graph for Item 1 Pre-test Exp Group</td>
<td>67</td>
</tr>
<tr>
<td>4.9. Graph for Item 1 Post-test Exp Group</td>
<td>68</td>
</tr>
<tr>
<td>4.10. Graph for Item 5 Post-test Exp Group</td>
<td>69</td>
</tr>
<tr>
<td>4.11. Graph for Item 2 Post-test Exp Group</td>
<td>70</td>
</tr>
<tr>
<td>4.12. Graph for Item 2 Post-test Exp Group</td>
<td>71</td>
</tr>
<tr>
<td>4.13. Graph for Item 1 Post-post-test Exp Group</td>
<td>72</td>
</tr>
</tbody>
</table>
CHAPTER 1:  
INTRODUCTION

As a seasoned veteran teacher with over 15 years of experience, it has been my goal since day one of teaching to give students the tools they need to be successful in life, and just as importantly, to be productive citizens of society. The vehicle I chose over two decades ago to help accomplish this is science, specifically earth science. After many years of furthering my education in science teaching and being part of other research opportunities, I have come to the idea that perhaps discovery learning may help students gain the skills they need to be successful.

In my work with other researchers, I have also come to understand that there are roadblocks in the way for students in the science classroom. Those barriers are misconceptions or alternative conceptions that students hold as beliefs and truths. As I came to understand how misconceptions can restrict students’ learning in science I decided to make part of my educational goal to help students overcome them. The biggest misconception that I have encountered in science is students saying “I can’t do science,” which has led me to understand that if students believe they cannot do something, they usually do not even try to do it.

So the basis of the research outlined on the following pages is my quest to find a way to make a difference in students’ learning and perception of science. I do this because I believe it is my duty as an educator and an American citizen to try and help students gain the tools they need to learn, and become productive citizens.
Statement of the Nature of the Problem

One goal of science education in the United States should be is to keep the U.S. competitive in the science world. To do that it needs to start with science education and students’ attitude toward science. Lent, Brown, and Larkin (1984;1986) found that students who have a more positive attitude or better self-efficacy about science are more likely to perform better in science classes. So the idea is that if students feel like they can do science they will achieve better in science. Unfortunately there may be unforeseen circumstances that contribute to students’ dislike of science and their ability to succeed in science such as misconceptions about scientific concepts.

Research suggests that students entering the science classroom possess misconceptions about how the real world operates (Taiwo, Ray, Motswiri, & Masene, 1999). Although it would be nice to start with classes of students who have completely clean slates, children even at an early age have their own understanding about how the world they live in works (Henriques, 2002). Most teachers may be aware that many students in a class may perceive a single phenomenon of nature in a completely incorrect fashion (Crockett, 2004) which may be what is known as a misconception.

Knowledgeable science educators understand that their role is to help students build good conceptual frameworks about processes and concepts in science. To accomplish this goal, these educators understand that they may need to help students identify their alternative conceptions, challenge those alternative conceptions, and replace them with a correct understanding of the concepts in question. Identifying the alternative conceptions that students possess can be the most troublesome part. Libarkin and Kurdziel (2001) suggest that there have been good conceptual inventory tests created in
other realms of science such as physics and chemistry, but there was a gap in the
geosciences for an inventory that will identify student misconceptions. Labarkin and
Anderson (2005) described for the STEM Assessment Conference, their development and
use of the Geoscience Concept Inventory (GCI) with use of higher education students,
which may not be completely suitable for middle school students. If misconceptions can
be identified for middle school students, the use of discovery learning in the classroom
may be able to allow students to confront their misunderstandings, allowing them to
disprove them and correct them. The use of discovery learning will be based on the
description of inquiry and discovery-oriented instruction as presented by Sutman,
Schmuckler, and Woodfield (2008). They state that by using these practices it “enables
students to develop and practice many investigative skills in the search for the answers to
their own inquiries” (p. 4). Incorporating these tactics into classroom learning
environments may help students grasp abstract concepts and may help them to overcome
any misconceptions they may have about those concepts.

**Specific Research Questions**

This investigation will examine the following research questions:

1. Does the use of discovery learning – enabling students to develop and practice
   investigative skills in the search for the answers to their own inquiries – affect
   students’ understanding of the processes involved in the water cycle?

2. Does the use of discovery learning affect students’ self-efficacy about science?

3. What misconceptions do students have about water in the atmosphere and the
   processes of the water cycle?

4. What is the origin of a misconception identified by this study?
Definition of Terms

Cognitive Learning Theory

“The cognitive approach focuses on making knowledge meaningful and helping learners organize and relate new information to prior knowledge in memory”

(Yilmaz, K. 2011, p. 205)

Discovery Learning

Prince and Felder (2006) define discovery learning as “an inquiry-based approach in which students are given a question to answer, a problem to solve, or a set of observations to explain, and then work in a largely self-directed manner to complete their assigned tasks and draw appropriate inferences from the outcomes, ‘discovering’ the desired factual and conceptual knowledge in the process (p. 132).

Misconception

“Misconceptions correspond to the concepts that have peculiar interpretations and meanings in students’ articulations that are not scientifically accurate” (Bahar, 2003, p. 56).

Self-efficacy

Bong and Clark (1999) define self-efficacy as a person’s own cognitive perception of his/her capabilities at a task.
Traditional Instruction

As defined by Kahn (1997) traditional instruction includes the following:

1. Teacher talk exceeds student talk.
2. Instruction occurs frequently with the whole class; small group or individual instruction occurs less often.
3. Use of class time is largely determined by the teacher.
4. Teachers look upon the textbook to guide curricular and instructional decision making.
5. Classroom furniture is arranged into rows of desks or chairs facing a chalkboard.

(pgs 41-42)
CHAPTER 2
REVIEW OF LITERATURE

Misconceptions in Science

The preexisting, incorrect frameworks that students have can be very strong and deeply rooted. Students use what they know, or in many cases what they think they know, as foundations in building new knowledge (Sewell, 2002). Evans (2008) suggests that students have naïve theories about the natural world and these “naïve theories provide the commonsense intuitions that first come to mind when humans seek everyday explanations for natural phenomena,” (pg. 2) For these reasons, despite the vigor and persistence of a teacher, the prior misconceptions held by children may hinder or taint the understanding of a new topic (Trumper, 2001). For instance, Henriques (2002) points out that many students believe frost falls from the sky when in actuality frost forms when air containing water vapor comes into contact with surfaces on the earth below the freezing point. The water deposits (when gas turns into a solid skipping the liquid phase) as ice crystals. Complicating the situation even further is the idea that understanding in science is a gradual learning process that becomes reconstructed and reinforced based on students’ perceptions of the physical world (Pine, Messer, & St. John, 2001). This being the case, Pine, Messer, and St. John’s (2001) findings reiterate the notion that preconceptions about science must play a role in the whole process of learning science.

Recognizing that students may possess misconceptions about all subjects in science is the first step in overcoming them. Although much research has been conducted about misconceptions in science, less has been done in the specific field of earth science than other branches of science. Most of the work completed thus far
involves physics, chemistry, and life science with less showing up in earth science (Chang & Barufaldi, 1999; Henriques, 2002). The need for research to be conducted in earth science education is also backed by many professional organizations such as NASA, University Space Research Association’s Earth System Science Education, and the Geological Society of America (Henriques, 2002). Earth science is a required part of secondary education; therefore it is imperative for professionals to understand how to improve achievement in earth science (Chang & Barufaldi, 1999).

One of the areas in earth science that needs improvement is meteorology. This is one of the realms of earth science that students need to understand to obtain an adequate understanding of real world scientific phenomena. The need to look at students’ views about meteorological processes becomes important due to its inter-disciplinary nature that encompasses multiple areas in the world of science (Henriques, 2002). Likewise, Choi, Niyogi, Shepardson, and Charusombat (2010) suggest that students have misconceptions about global climate change because students have difficulty connecting science concepts that are interconnected. Because meteorology is taught in earth science classes early in many school curricula and has an inter-disciplinary framework, it is logical for teachers to locate and overcome misconceptions so that the alternative conceptions do not complicate learning in later years during high school. In fact Ben-zvi-Assarf & Orion (2005) explain that many students enter junior high school with misconceptions about the water cycle and graduate with the same misconceptions. They also found that students view the water cycle as individual pieces instead of interconnected set of processes.

Keeping students’ conceptions of meteorology correct so they do not interfere with later learning can be problematic. Because describing processes in the atmosphere
involves gases that are invisible to the students, the concepts that are covered within a classroom become less concrete and more abstract. For instance, students can see a river flowing carrying sediment and moving pebbles, but they cannot see water vapor in the air or the heat in the air that allows that water vapor to exist. This is why many children have the idea that air “holds” water vapor instead of heat allowing water vapor to exist. Bar (1989) also found similar misconceptions. He found that students believed clouds are made of water vapor, they are like sponges that soak up water, or they are like bags that explode water when it rains. These ideas can, in turn, increase the likelihood that students will form misconceptions to explain processes in nature (Dove, 2002) especially when it comes to processes they cannot see as in the water cycle. Bar (1989) also found that students tend to hold onto their original incorrect ideas about the water cycle and create incorrect supporting evidence to help explain the misconceptions they hold. It also does not help that the everyday language that teachers use to try and make the water cycle less abstract can in itself create misconceptions because of the way students already perceive the examples that teachers are using (Eshach, 2003). Choi et al. (2010) reiterate this notion stating that simplified explanations of complex concepts can lead to students creating misconceptions or even reinforcing misconceptions that student may already hold.

Chi (2005) suggests that some scientific processes are more likely to create misconceptions than others. She generalizes that there are two main types of processes in science: direct and emergent processes. She describes the direct processes as confined and more straightforward like the circulatory system where blood is pumped directly by the heart through veins of the body. She describes emergent or indirect like diffusion in
water where movement is based upon unseen pressure gradients. She suggests that
because of the abstract thought involved in explaining emergent processes, students can
create and hold on to misconceptions about how the processes work for example in the
water cycle, how and why water evaporates where water vapor is being grabbed and held
by air molecules.

Using the processes of condensation and evaporation, it has been shown that
students may be able to use the terminology correctly to indicate what states of matter the
water is in before and after the processes of condensation and evaporation, but cannot
accurately describe how the processes work. Therefore, they only show that they know
what the processes are, but they do not show that they fully understand how evaporation
and condensation occur (Tytler, 2000). Therefore they use what they think they know
about evaporation and condensation to describe how it happens which creates
misconceptions about those processes. Ben-zvi-Assarf and Orion (2005) found “that
students in all grades had misconceptions concerning basic physical and chemical
processes such as evaporation, condensation, and dissolution, which are important for
understanding the transportation of matter within the water cycle” (pg 369). This can lead
to misconceptions like water can only evaporate from lakes and oceans or clouds form
through condensation because cold air cannot “hold” as much water as warm air
(Henriques, 2002). Henriques has also noted that there are other misconceptions in
meteorology including what students think clouds are (sponges that hold water) and how
they form. Likewise, Pine et al. (2001) found that students have alternative ideas about
buoyancy, where they believe things that are small will float and things that are big will
sink.
The first step in overcoming misconceptions, including those in meteorology, is knowing what those misconceptions are. Ben-zvi-Assarf & Orion (2005) used a time intensive questionnaire, diagram drawing, and interview approach to identify students’ misconceptions about the water cycle. Likewise, Cardak (2009) used an extensive diagram and interview approach to identify misconceptions about the water cycle. Unfortunately, most teachers, bound by their curriculum, do not have the time to identify students’ alternative frameworks (Henriques, 2002). Many studies that are effective in identifying alternative conceptions take an extensive interview approach to identify the misconceptions (Griffiths & Thompson, 1993), which is very time consuming when teachers have limited time to cover the set curriculum.

Identifying alternative conceptions in an individual classroom can be a lot less time-intensive for a teacher than doing an in-depth interview with each student. A teacher can introduce a topic by holding a general classroom conversation with his or her students rather than conducting a standard lecture. By allowing the students to discuss the topics in a more relaxed atmosphere, the teacher may be able to recognize misconceptions as they are discussed in conversation (Crockett, 2004). Slotta and Chi (2006) suggest that students need to face a misunderstood previous understanding, or rather a misconception, and that it is the teacher’s responsibility to first check for students’ preconceptions about scientific concepts prior to embarking on new learning about those concepts.

Overall, therefore, it is evident that misconceptions can create barriers that make it very difficult for students to learn scientific principles. As students are presented with new concepts the students have to decide what to do with the new material based on what
they now and understand. How they incorporate this new knowledge into their psyche can be dependent on their background knowledge of either the subject or other natural phenomena (Chinn and Brewer, 1993). The critical issue that must be confronted is to determine how best to overcome these misconceptions.

It is one of the central tenets of this dissertation that the conventional, teacher-centered approach to scientific instruction is not an effective approach. The approach that seems to hold promise is based on the construct of discovery learning. The rationale for this belief is set forth in the next section of this literature review.

**Overcoming Misconceptions**

Posner, Strike, Hewson, and Gertzog (1982) explain that there are two levels of conceptual change that students undergo. When students are first presented with new information they sometimes use their understandings in their existing schema to help explain the new concept, which the researchers call assimilation. The second level presented is called accommodation in which students’ existing understandings can not account for the new concept, so they have to either rearrange their existing ideas to make the new concept work, or completely replace the idea. Also, Pintrich, Marx, and Boyle (1993) suggest that conceptual change in science follows a constructivist “hot” model. Their interpretation of the hot model states that the “process of conceptual change is influenced by personal, motivational, social, and historical processes” (p. 170). They suggest that there is evidence that learning then is partly emotional, motivational and social. Therefore, in order for individuals to disregard pre-existing ideas they may first need to become dissatisfied with the concept. Then they need to find a new explanation that is intelligent and makes sense to them; but to do that they must understand the
processes involved. It also means that the explanation must fit into other existing ideas that make sense to them (Dole & Sinatra, 1998). Dole and Sinatra state, “the new conceptions must not only make sense and be comprehensible, but they must be believable” (p 113). This process can be difficult and problematic depending on how deeply rooted the misconceptions are (Gonen, 2007). It is worth noting that Gonen (2007) suggests that many physical interactions in the real world are difficult to explain, which is why students often create alternative views of how natural phenomena work.

When Gonen’s (2007) ideas and Dole and Sinatra’s (1998) ideas are combined with the cognitive development level of middle school students, building and holding onto misconceptions about abstract processes becomes a natural and viable aspect of middle school students’ learning repertoire. Although tackling misconceptions can be a priority of teachers for any students at any age, focusing on having adolescent students in middle school overcome them can be very effective. As Blakemore and Firth (2005) have suggested, “the brain is still developing during this period, the brain is adaptable, and needs to be molded and shaped” (p. 462). Since the brain is adaptable and moldable during these years it can be easier for individuals to challenge and overcome their misconceptions.

Eshach and Schwartz (2006) describe in their research about students’ understanding of sound waves that sometimes students can make sensible statements about how sound travels, but upon further questioning, misconceptions can surface. Students are placing new understanding in old schema that are correct, but the correlation is incorrect. This shows how students can hold on to a belief or try to fit all new understanding into what they already know. Eshach and Schwartz (2006) also suggest that
by describing students’ understanding of sound waves, teachers knowing what their students’ misconceptions are at the beginning of a lesson can help teachers tailor their decisions about instruction to consider these misconceptions. Eshach and Schwartz suggest that dialogue about the everyday uses of waves and what waves mean in physics can help teachers identify misconceptions. Using this idea, the same can be accomplished for the processes in the water cycle.

Identifying a misconception is only the first step toward overcoming alternative frameworks that characterize students’ thought process. Because some of the misconceptions are rooted deeply in students’ understanding of science and those roots are many times based on cultural beliefs, it can be very hard to uproot the misconception and make it correct (Taiwo et al., 1999). A cultural belief can be a religious belief such as God and angels cause lightning and thunder (Henriques, 2002). The psychological idea that most humans do not like to change what they are comfortable with makes it understandable that students will only modify what they believe if it no longer serves a purpose in their psyche or in their lives (Sewell, 2002). Chinn and Brewer (1993) suggest that “in order to change an entrenched theory, it may be necessary to figure out precisely why the theory is entrenched, that is, to identify those crucial components of the theory that are most deeply entrenched” (p. 32) Therefore, one way to overcome misconceptions that students hold is to have them challenge those misconceptions. When students are presented with conflicting understandings about an idea or even a process in science, they have to do something with the new information: reject it or more intensely test it (Henriques, 2002). Dole and Sinatra (1998) have suggested that the pre-existing conceptions that students have and how easily they are changed can be based on
“strength” or how strong, and well developed the conception is, “coherence,” how well it fits in to the students’ background knowledge, and “commitment,” which “can come from a variety of sources, such as sensory experience, social group membership, or cultural background” (p. 118). Therefore students conceptions that are incorrect and have a high strength, coherence, and commitment will be difficult for students to overcome.

Chan, Burtis and Bereiter (1997) have shown that using a problem-based model of learning may help students to overcome some of the misconceptions that they hold. By approaching new material allowing students to use discovery learning, students are able to confront their misconceptions and may be able to see the flaws in their original understanding of concepts. This will allow them to question and challenge the misconception, thus eventually overcoming their incorrect ideas (Galili & Hazan, 2000). Chan, Burtis and Bereiter (1997) also conclude that students may even see inconsistencies in their way of thinking; but unless the students are engaged in what they call a “knowledge-building activity” they may not truly overcome their misconceptions, but rather hold on to their pre-existing ideas once the lesson moves on. Dole and Sinatra (1998) agree that for the greatest chance for conceptual change to occur students need to be engaged in the classroom, and not passive recipients of knowledge. Paralleling the same idea Pintrich et al. (1993) suggested that traditional classrooms do not facilitate conceptual change.

Teachers’ approaches to how a curriculum should be covered can have an astonishing effect on students’ ability to reconstruct pre-existing knowledge. Although a typical textbook curriculum uses sequencing information in order for students to learn information, the sequencing is not very effective in students gaining a deeper
understanding of concepts, especially if they hold misconceptions about the concepts being covered. The sequencing structure allows students to use rote memory, but not construct alternative ideas, whereas a problem-based approach forces them to look at the information from many perspectives (Chan et al., 1997). Chan et al. suggests that in order for this to happen, the teacher needs to shift from teacher-centered instruction to teacher-assisted instruction with a student centered classroom incorporating a problem-centered inquiry approach.

Using misconceptions as problems that students must solve can be a positive shift in the correct pedagogical direction. Research has shown that using problem-solving instruction increases science achievement and has been able to restructure the way students think about concepts in science (Chang & Barufaldi, 1999). The process involves students carefully examining a problem and the possible results, creatively thinking about the concept, and finally testing the way they perceive the concepts. Cordova, Sinatra, Jones, Taasoobshirazi, and Lombardi (2014) showed that by using refutation text, which addresses common misconceptions, students were successful in having conceptual change about science concepts. They showed that using this approach the students with the low self-efficacy, interest, and confidence but with many misconceptions were able to significantly increase there understanding of scientific concepts and overcome misconceptions. However they did find that students in this group were not as successful in retaining the understanding of the new concepts over time and suggested that it may be due to their low interest in the subject and low self-efficacy about science.
The problem-based system allows students to use their own skills, senses, and perceptions in order to make phenomena meaningful to them. This in itself may not only help students overcome misconceptions, but also develop higher level thinking skills while they are applying the concepts instead of just using rote learning skills to regurgitate textbook definitions on a test (Chang & Barufaldi, 1999). Likewise Franke and Bogner (2011) found that by having students confront their misconceptions, students not only overcame the misconceptions, but increased their cognitive achievements and mental efforts, as well as increasing the instructional efficiency of the class. Therefore, by identifying the misconceptions that students hold, eighth grade students should be able to challenge and overcome misconceptions while giving them a better learning experience.

**Discovery Learning**

One way to help students challenge misconceptions and achieve higher understanding of a concept can be the use of discovery in the classroom. Prince and Felder (2006) defined discovery learning as “an inquiry-based approach in which students are given a question to answer, a problem to solve, or a set of observations to explain, and then work in a largely self-directed manner to complete their assigned tasks and draw appropriate inferences from the outcomes, ‘discovering’ the desired factual and conceptual knowledge in the process” (p. 132). Discovery learning, when used in the educational environment, is a problem-solving approach to learning where the teacher acts as a facilitator for the students who work through a given problem (Fuller, 2001). Gurses, Acikyildiz, Dogar, and Sozbilir (2007) reiterate the idea that the classroom needs to move from a teacher-centered model to a student-centered environment. The teachers’
role in the classroom should be that of a guide where they probe and support students’ initiatives. Blakemore and Firth (2005) suggest, “perhaps the aims of education for adolescents should change to include strengthening of internal control, for example, self-paced learning, critical evaluation of transmitted knowledge and meta-study skills” (p. 462). Discovery learning allows students to be the center of learning, where they learn at their own pace. It gives them the opportunity to evaluate on their own transmitted knowledge and enables them to confront misconceptions head-on.

Although many educators steer clear of inquiry for fear of giving students freedom to approach problems the way students want which can veer them far from the desired content, discovery learning is not pure constructivism. Discovery learning, however, does fall within the realm of the Cognitive Learning Theory. Yilmaz (2011) states that “the cognitive approach focuses on making knowledge meaningful and helping learners organize and relate new information to prior knowledge in memory” (p. 205), which is the goal of discovery learning. Also in line with discovery learning cognitive learning theory suggests that learners need to be actively involved in the acquisition of knowledge while using self-planning to organize how they go about it. Cognitivists would also agree that students need to be encouraged to make connections between new material and previously learned knowledge (Yilmaz, 2011).

In a well-orchestrated discovery learning environment, questions and problems can be posed by the teacher and not necessarily just the students (Sutman et al., 2008). The students, then, have the leeway to approach the problem from their own angles and incorporate their own strengths. The idea is that students will be engaging in inquiry because they will have to ask questions about the main idea, describe events, construct
their own explanations, and judge these ideas against how scientists describe the phenomenon (Sutman et al., 2008). Therefore, discovery learning is a guided inquiry that has more structure than true inquiry, allowing teachers to keep the focus on the curriculum they have to cover, while still permitting students to acquire inquiry skills. Balim (2009) showed this in his 2009 study; by allowing students to engage in discovery learning, they had significant gains in their inquiry skills over students that were taught in more traditional classes that were lecture based. Guzetti, Snyder, Glass, and Gamas’ (1993) also found similar ideas in their meta-analysis of instructional interventions. They suggest that many studies incorporated “cognitive dissonance by requiring students to defend their positions with information from the text and by provoking interactive discussion in which direct questioning helped students rethink their prior conceptions (p. 134). They concluded that science studies that used cognitive conflict had the greatest affect on students.

According to research done by Hsiao-Ching (2005), a teacher’s first priority in designing a lesson should be to design it so it is meaningful for students and that it is not intended for students to just memorize facts. His study found that by creating meaningful lessons, student achievement and retention of concepts were greater than those of students who were not immersed in a meaningful lesson. Likewise, Limon 2001 suggested that in order for a lesson to be successful in producing cognitive conflict, students needed to be interested in the content, motivated, and needed to use pre-existing knowledge to complete the lesson. Ogu and Schmidt (2009) suggest that teachers should construct lessons that build on their prior knowledge and interests so it can help motivate and engage children, which leads to meaningful lessons. Hsiao-Ching’s (2005)
description of this meaningful classroom lesson is a parallel description of a discovery lesson in science. He also showed that the idea of a discovery lesson is highly effective in allowing adolescent students to grasp abstract ideas like that of atmospheric pressure.

Gantasala and Gantasala (2009) found that course design and curriculum that parallel students’ learning styles improved academic scores and improved students’ attitude toward learning. They also suggest that it is the educator’s job to show not just the what of learning, but also the how and why of learning which promotes understanding. The same idea is supported by Pastrana (2009) where he suggests that by allowing students to engage in learning through different media students’ interest can be stimulated which can lead to active participation in class and the learning process instead of being a passive recipient of knowledge. Therein lies the purpose of discovery learning. Different students can engross themselves into a problem using their own passions to arrive at the same outcome along different avenues of knowledge acquisition.

AK (2008) suggests that learning can be broken into two categories, surface and deep. In surface learning, students rely on rote memorizations; whereas in a deep approach to learning, students reach for an understanding of a topic beyond just knowing factual information. Since students’ learning goals can affect their academic performance, teachers should encourage deep learning, not just surface learning. Because the water cycle is presented in very simplistic terms early in students’ educational careers, it lends itself to surface learning. Therefore the true understanding of how it works and how the processes interact are never acquired. Because deep learning is intrinsic and needs to be self-motivated for the learner’s own gratification of understanding a subject, the teacher cannot tell the students they will take a deep
approach but rather the students decide whether or not they will take a deep or a surface approach. Therefore, it is the teacher’s responsibility to construct a dynamic lesson that ignites and encourages students to be intrinsically motivated (AK, 2008). Using discovery learning in the classroom gives the students ownership of their learning and can lead to students becoming intrinsic learners.

This, however, does not mean that students need to be left alone to figure everything out. With no guidance at all some students may never get to the final answer of a set problem. Discovery learning does require some sort of guidance. Depending on the desired learning outcome different levels of guidance may need to be considered. The underlying idea, however, is that no matter what level of guidance is offered, students need to discover the goal information on their own for it to be intrinsically satisfying and meaningful (Alfieri, Brooks, Aldrich & Tenenbaum, 2011). Mayer (2002) also agrees and suggest for learning to be meaningful the student learning should be broken down into the following steps:

(a) problem representation, in which a student attempts to understand the task and generate possible solutions
(b) solution planning, in which a student examines the possibilities and devises a workable plan
(c) solution execution, in which a student successfully carries out the plan.

(Mayer, 2002 p. 231)

Barratt (1975) states that many times the promotion of formal thinking skills is neglected in students during their adolescence. His research suggests, however, that discovery learning and problem-solving techniques help to nurture formal thinking skills
in adolescents while increasing their academic performance. By using a problem-based
discovery approach Gurses, Acikyildiz, Dogar, and Sozbilir (2007) found that students
using this method had higher achievement than they previously did before the
introduction of a problem-based approach. Not only did achievement increase, but
students’ problem solving skills increased as well. The students were also able to make
connections between the content and the real world, making the learning more concrete
and sustainable. Because the students were actively involved in the learning process,
they became intrinsically motivated.

Mao and Chang’s (1998) study about inquiry-oriented instruction of earth science
in 9th graders found that there was not a difference in achievement between traditionally
taught classes when it came to knowledge level items. However, they did find there was
a significant difference in achievement between inquiry-oriented and traditional
instruction when it came to higher -level comprehension concepts and concepts that were
integrated. Similarly diSessa (1993) suggests that on the surface students may seem to do
well in class by earning outstanding grades. In reality diSessa has found when it comes
to truly understanding what the students have learned, they can “do” the class, but do not
understand what they have done. He contends that if students are not connecting what
they learn to their everyday lives, they can miss the complete comprehension of the idea.
Likewise, Gunckel, Covitt, Salinas, and Anderson (2012) found that students may be able
to simplistically describe the water cycle in a textbook diagram, but they do not
understand the underlying processes that drive it or how it fits into an earth systems
approach of interconnected systems. They also contend that students do not understand
the underlying driving forces of the processes. Clark, Sibley, Libarkin, and Heidemann
(2009) found similar results. They showed that students understood the basics of the water cycle, but until they confronted the ideas in a social setting with other group members so they could discuss problems about steam above a coffee cup, they were unable to realize that the water cycle is more complicated it initially appears. This questioning and discussion of a problem is a form of Discovery Learning.

By using a social context of learning in a discovery learning environment students may become more motivated to learn and may even change their attitude toward science. Moa and Chang (1998) found that the inquiry-oriented groups had higher achievement, and also that the students had a more positive attitude toward science and the learning of science. Also, the researchers found that the test group had more confidence about science and doing science.

**Self-efficacy**

From motivational posters to motivational speakers, people hear and see time and time again that attitude is everything and that your attitude determines your achievement level, or to put this more colloquially, your attitude determines your altitude. This generalized statement also holds true in academics. Bandura (1993) showed that students with a higher self-efficacy in a class outperformed students with lower self-efficacy, and also that students with the higher self-efficacy were able to raise their own personal goals about the class. Students with higher self-efficacy were able to motivate themselves to complete classwork outside of school even when other more interesting things were going on. The students were also able to meet academic deadlines more effectively than students with lower self-efficacy.
Many researchers believe that students’ attitude and self-efficacy for a subject is as important to consider as the curriculum itself. Pajares and Miller (1994) suggest that, “school practitioners should be looking at students’ beliefs about their capabilities as important mediators and predictors of performance” (page 201). However, Bitner and Pajares (2001) suggest that looking at students’ self-efficacy is a better predictor of academic performance than student attitude or self-concept. Bong and Clark (1999) explain that the difference between self-efficacy and self-concept is that self-efficacy is a person’s own cognitive perception of his capabilities at a task, whereas although self-concept does include a cognitive perception, it also is influenced by one’s social comparison of others.

Ramdass and Zimmerman (2008) suggest that students’ lack of self-efficacy can be a major liability to students especially elementary and middle school students. Because of this they recommend that a classroom should nurture the belief in students that they can succeed. It has been shown that students with the same cognitive skills can have different outcomes and different levels of academic performance depending on their perceived ideas about how well they can do in a specific class.

With the strict No Child Left Behind (NCLB) guidelines with which all educators are faced, improving students’ performance is mandatory. Even though NCLB has no science guidelines, it has impacted elementary science by reducing how much of it is incorporated into the classroom in order to leave room for improving, reading, writing, and mathematics scores in schools. However, even though the NCLB has focused educators’ attention on the achievement of all students regardless of academic level, lower aptitude students with lower levels of cognitive ability still seem to be struggling.
Thus, any way to help this group of students is a top priority for many educational institutions. Starting with students’ self-efficacy may be the key. It has been shown that lower ability students have the greatest increases in academic performance when they improve their self-efficacy about a subject (Multon, Brown & Lent, 1991).

One way to improve self-efficacy is to design instruction in a way that is different from the way it is typically conducted using a lecture based classroom where students sit and take notes, or in science using a pre-produced lab where the students just follow the steps that are laid out for them. Using problem-solving and self-directed lessons, students are in charge of their knowledge acquisition. Research has shown that this method of instruction increases students’ understanding of science concepts (Hsieh, Cho, Liu & Schallert, 2008). Hsieh et al. (2008) also found that “students developed self-efficacy for the science unit through collaboration with peers and autonomously learning science through their own exploration of the science topics.” (page 45). Likewise, Akcay, Yager, Iskander, and Turgut (2010) found that by using a discovery learning type of approach middle school students developed more positive attitudes toward science. They also found that students embedded in the less traditional learning environment that did not just focus on a book curriculum received a more meaningful learning experience by gaining a deeper understanding of science ideas, developing better process skills, and developing organizational schemes for achieving science literacy.

Akcay et al. (2010), suggest that there are multiple reasons that students develop negative attitudes toward science especially in the middle school years. They cite that by middle school there is more emphasis on factual information and test results. They also suggest that because of this, middle school students do not get the opportunity to actually
do science where the students are involved in the entire science process. Rather they are learning about science where the teacher tells them what scientist have found, leaving less opportunity for students to enjoy true science.

The higher standards of factual information and testing scores that Akcay et al. (2010) describe can affect lower ability students as well. The high standards create situations for their self-efficacy in science to fall. Schunk and Zimmerman (2007) also support this, where the researchers attribute low ability students’ lower self-efficacy to the students believing their achievement is limited by their ability. Simply stated, if students think they cannot do well in science class then they will not try as hard in the class and end up doing poorly. But Akcay et al. (2010) found that by using an alternative learning environment, the lower ability students were able to develop a more positive approach toward science.

Summary of literature

After reviewing the literature, it can be said there are many variables that can affect students understanding of scientific concepts. Two of these variables are students’ misconceptions in science and their self-efficacy in science. The misconceptions taint the students’ learning by putting roadblocks in the path of understanding while students’ lack of self-efficacy hinders learning by false assumptions students possess about their ability to learn and understand science. The literature also suggests there are ways to give students deeper understanding about science and change their existing self-beliefs about science using strategies such as discovery learning in the science classroom.

The literature reviewed here does not directly support the proposed research questions of this study, but I believe there is enough supporting evidence from the
literature to suggest that discovery learning will have a positive effect on students’ understanding of the water cycle as well as helping them to overcome misconceptions they have about it. By allowing the students to grow as science thinkers I believe the literature also suggests that students’ self-efficacy in science should increase as well. Although the literature does not specifically state any of these outcomes, the underlying outcomes of the previous research are supportive to the questions of this study and should be asked and tested.
CHAPTER 3

METHODOLOGY

Sample

The sample was drawn from the eighth grade students enrolled in an upper middle-class suburban junior/senior high school in southeastern Pennsylvania with a class size consisting of approximately 150 students. All of the eighth grade students at the school are required to take earth and space science as a major subject for one 41-minute period per day for half of a school year. During the fall semester of 2012 approximately half of the eighth graders took earth and space science while the other half took a physical science class. After the semester, the students switched classes. I am the one who teaches the earth science classes. The building administration as well as the guidance faculty determined which students had earth and space science during the first semester and which students had it during the second semester. The school uses a computer program to create a master schedule of all the teachers’ schedules based on the needs and the number of students to be placed in every section. Once the preliminary schedules have been run and set by the computer program, the guidance staff reviews the master schedule and the number of students in the sections in order to manually move students in and out of similar sections. They do this to try and even out the class sizes to keep sections from being either too large or too small.

The eighth grade students were placed into one of seven sections (depending on class size) of earth and space science or physical science with half of the sections being in earth science and the other half in physical science. Both the earth and space science and the physical science classes have two different academic levels, advanced and academic.
The students’ placement into the different levels is based on their performance in science during seventh grade and by their reading and writing ability on standardized tests. The academic classes are composed of average to below average achieving students as well as most of the special education students in the 8th grade class. The advanced classes consist of high achieving students and students that are labeled as gifted. The only exclusions from the study were severely mentally challenged students who do not take a science course or special education students whose Individual Education Program (IEP) legally prohibits testing situations or question types that were used in the data collection instrument.

Because the test site is a public institution and because the tests were administered to minors, a permission slip was sent home to the parents/guardians of each student in order to obtain permission to use the student’s responses in the study. The permission slip can be seen in Appendix A. All students were excluded if they returned the permission slip with a request not to have their responses used or if they did not return the permission slip. Students were also given a student assent form to read and sign so they understood that their responses would be used for this study and what their rights were during the study.

Due to the construct of the school’s curriculum the students in the physical science class did not get the same content during the study as the students in the students in the earth science class. The physical science classes were taught using traditional methods and not using discovery learning. Therefore, they are not a true control group, but rather a group used for a baseline comparison or a no-treatment comparison group.
The argument could be made that two of the earth science classes could have been used as an experimental group and two of them could have been used as a control group. Although this would have made for a better experimental design there were two limiting factors for this not happening. The first is I did not believe there would be enough data if they were split into two groups to give accurate statistically significant results and the second and most limiting is that the school district’s policy require that students that take specific classes no matter who teaches them, must be given the same curriculum including activities.

**Science Self-efficacy Survey**

Students’ self-efficacy in science was measured using a selection of items from Ketelhut’s (2010) study of Assessing Gaming, Computer and Scientific Inquiry Self-Efficacy in a Virtual Environment. The survey used in this research included eight items from Ketelhut’s (2010) survey that were adapted in order to address students’ self-efficacy in science. To adapt the Ketelhut’s (2010) survey, items were compared to that of Fraser’s (1982) Test of Science Related Attitudes-TOSRA survey, Thomas, Anderson, and Nashon’s (2008) SEMLI-S survey, and Parker’s (2010) Science Self-Efficacy Questionnaire. This step was completed to see what items other studies addressed so that I could choose the most important items from Ketelhut’s survey that would blend well with the research I conducted. The survey can be seen in Appendix B. The eight items selected were chosen in order to narrow the concepts from the survey to relate most directly to 8th grade students in their classroom. The items are in in five-point Likert format designed so that students can either agree or disagree with the statement.
The ratings are as follows:

5 = Strongly Agree
4 = Agree
3 = Uncertain
2 = Disagree
1 = Strongly Disagree

The original surveys had both positive and negative questions in them. An example of a positive question would be “Science is fun” whereas a negative question would read “Science is boring”. The eight questions used in this survey are all positive in order to avoid confusion in interpretation by the students.

The survey was given to every student before and after the lesson was conducted. To analyze the students’ self-efficacy the total average point value was calculated for each student and an overall average for each class was computed. The point value allowed easy analysis showing that the higher the overall value, the higher the student self-efficacy was. To analyze the effectiveness of the treatment an ANOVA was run on the difference of change in pre-lesson surveys and post-lesson surveys between the treatment group and the no-treatment comparison group. Also a total of how many students’ self-efficacy increased, decreased and stayed the same was calculated

**Misconceptions and Academic Performance Data Collection Tool**

The data collection tool that was used is based upon the tool used in a 2003 study entitled *Identifying Students’ Alternative Conceptions in Meteorology*. The findings from the trial were presented at the American Meteorological Society’s (AMS) Annual
Meeting in February 2003. In the study, 110 freshmen students were given the survey to attempt to identify students’ misconceptions about meteorology. The survey encompassed many areas of meteorology, including how water moves through the water cycle (Yoder & Pandya, 2003). Yoder and Pandya (2003) found in their study that out of all the areas that their tool covered, the processes in the water cycle and the concept of water in the atmosphere seemed to be the areas where misconceptions most likely occurred.

The current study adapted the questions pertaining to the water cycle and water processes along with basic structure of the survey from Yoder and Pandya’s 2003 study in order to identify misconceptions about water in the atmosphere and its transfer through the water cycle. This tool was chosen over the Geoscience Concept Inventory due to its content concentration. I also felt that the Yoder and Pandya (2003) questionnaire more specifically fit the sample population’s curriculum and age level. The new data collection tool consists of nine multiple-choice questions that can be seen in Appendix C. Each of the nine items on the tool encompasses one or more of three general underlying scientific concepts:

1. Properties of the states of matter
2. Changing between states of matter
3. Energy’s involvement in the states of matter and changing between the different states.
The distractors that were used on each of the questions represent feasible choices for individuals who may hold misconceptions about the processes within the water cycle. The following describe the rationale for the distractors used in each question.

1. When you look at a cloud you are looking at:

   A. Water vapor
   B. Smoke
   C. Steam
   D. Liquid water and/or ice

The correct answer is D. This questions underlying principle is the first one, properties of the states of matter. Under most natural circumstances, gasses are not visible to the naked eye. Since water vapor is a gas it cannot be seen, but a collection of microscopic water droplets or ice crystals can be seen. Smoke on the other hand is a concentration of microscopic particulates that are the by-product of combustion. Lastly steam, which is similar to clouds, is a collection of microscopic particles of water droplets that are leaving the surface of water where the air is convecting over warmer water, but the steam usually evaporates as it rises.
2. Warm air allows more water vapor to exist in the air because:

A. There is more space between air molecules for the water molecules

B. There is more energy available for water molecules to be the vapor state.

C. Warm air is more dense.

D. Warm air exerts more pressure on the water molecules.

The correct answer is B. This question encompasses all three of the underlying principles. As water molecules acquire more energy they become more energetic and eventually will be able to have to become a gas due to their kinetic energy gain. Even though the warmer atmospheric temperatures cause the air molecules to spread out, the water molecules do not sit in the “spaces” between other molecules but rather exist alongside of them. The spreading of molecules decreases the density, which would decrease the pressure. Also the water vapor is not held in the air by the pressure the atmosphere exerts. In fact higher pressure will make it more difficult for water to evaporate.

3. Which statement is true?

A. Water can evaporate at any temperature.

B. Water can only evaporate if it is boiled.

C. Water can only evaporate at 100° C.

D. Ice has to melt before it can evaporate.
The correct answer is A. This question involves the second and third underlying principles. Because evaporation can take time in nature, some students may only have sat and watched it happen while water boils. And yes water does boil at 100° C, but water can evaporate just sitting around at room temperature. There is always a constant exchange of energy at the surface of water between the water and the air molecules that bump into them. Some of the molecules gain enough energy from this interaction to evaporate. This can also happen when the temperature is below freezing to solid water, it just takes a lot more of a transfer of energy to the water molecules.

4. Frost forms when:

   A. *Water vapor changes directly into a solid at temperatures below 0° C.*

   B. Dew Forms at temperatures above 0° C and then freezes when the temperature drops below 0° C.

   C. Snow falls to the ground at temperatures below 0° C and has stuck to objects at or near the earth’s surface.

   D. Rain falls to the ground at temperatures above 0° C and then freezes when the temperature drops below 0° C.

The correct answer is A. Like question number three, this questions underlying principles are the second and third about energy and changing states of matter. Water, whether it is liquid or solid, can accumulate on the ground without falling from the sky as precipitation. Freezing is a state change from a liquid to a solid, but frost goes through a process called deposition; the changing from a gas (water vapor) to a solid without going
through the liquid phase. By depositing, the water vapor releases much more energy than through the process of condensation, which in turn slows it to the solid phase.

5. What shape does a raindrop have?
   A. Like a pear
   B. Like a grapefruit
   C. Like a hamburger bun
   D. Like a carrot

The correct answer is C. This question has to do with the properties of the states of matter. Since water does not have a definite shape, its shape will depend on its environment. In space with the absence of a gravitational pull, the hydrogen bonding in the water will allow it to assume a spherical shape, but in the atmosphere the earth will pull the water towards it, and the air, which has mass, will exert resistance on the water and change its shape. The hydrogen bonding will allow a drip of water that falls out of a spigot to cling on and stretch out like a teardrop until gravity prevails. Finally, although being build pointy to be arrow dynamic would increase the waters speed as it falls, water is not built and the air pushes back on the water flattening the bottom.

6. For clouds to form:
   
   A. Air needs to rise.
   B. Air needs to sink.
   C. Air needs to move horizontally.
The correct answer is A. This question incorporates the underlying principles two and three. As air moves vertically either up or down, it will undergo changes of atmospheric pressure. Changing the pressure to the air changes the temperature of the air. Move toward the surface of the earth and you increase the pressure that increases the temperature. Move the air up and the opposite happens. Lower temperatures mean that there is less available energy, which means less energy to keep water in the vapor state. Having less energy to keep water vapor means that the vapor will have to condense. Yes it is true that as you watch clouds move by, they can change shape and grow, however it is the vertical movement that allow them to grow.

7. What happens to a water molecule when it evaporates?

A. It contains more energy than it did when it was liquid water.
B. It separates into its elemental parts of oxygen and hydrogen.
C. It slows down and becomes suspended in the air.
D. It clings onto molecules in the air, which keep it in the air as water vapor.

The correct answer is A. This question has the underlying principles associated with changing states of matter and the energy exchange in order for it to change. For water to evaporate it needs to gain energy and speed up allowing it to change from liquid to gas. The water molecules are not hanging onto the other air molecules, but rather are existing with them. The air is comprised of different gasses like oxygen and hydrogen, but water does not spit into these gasses, that would be a chemical change and completely
destroy the water. Evaporation is a physical change where it stays water, just with more energy.

8. Which of the following would be more dense at sea level and 15° C?

A. Moist air

B. Dry air

The correct answer is B. The underlying principle has to do with states of matter and matter itself. Although on a hot humid day it may feel like one could cut the air with a knife, moist air is actually less dense than drier air. The atmosphere is an unconfined mixture of gasses. If more gasses are added to it, it expands to accommodate the extra gasses. Therefore if more water vapor is added to the mixture it expands allowing the water vapor to exist along with the other gasses. But this does move the other gasses out of the area. Since most of the atmosphere is nitrogen and oxygen, these would be the gasses that are replaced. The atomic weight of nitrogen gas (N₂) is 28 and the atomic weight of oxygen gas (O₂) is 32. Water’s (H₂O) atomic weight is 18, hence you replace a 28 or a 32 with an 18 and the air gets lighter, or more specifically less dense.

9. What happens when the relative humidity reaches 100%?

A. It rains

B. Condensation occurs

C. Air starts to rise

D. Air starts to sink
The correct answer is B. Question number nine’s underlying scientific principle has to do with changing of states of matter. It may be true that it is very humid when it rains, but the actual relative humidity at the surface of the earth where it is raining is often times less than 100%. Having a maximum relative humidity means that as much water vapor is in the air that can exist in the air based on the temperature. If you raise the air into the atmosphere any more it will cool and condensation will occur.

Accompanying each of the questions on the tool there was a four-point Likert scale to assess how confident students were in answering the questions. The Likert scale is as follows:

- Definitely do not know (1)
- Pretty sure I do not know (2)
- Pretty sure I know (3)
- Definitely know (4)

Each student’s test was evaluated looking for incorrect answers for each question on the test. Any incorrect answer that students gave with a Likert rating of 3 was considered a possible misconception. Likewise any incorrect answer with a rating of 4 was classified as a misconception. Any other ratings were deemed to be a non-conception instead of a misconception because negative ratings state that the participants either were pretty sure or definitely sure they do not know the answer implying they just guessed at the answer. To look for common misconceptions, the confidence levels were averaged, and any questions that had a majority of incorrect responses plus a confidence rating of 2.5 or higher was judged to be a possible misconception.
A second procedure was used to see if there were common misconceptions identified by the test. To calculate this, all of the incorrect responses from all the students were noted with a total Likert number being calculated for those questions by averaging the rating number. If the overall Likert rating was 2.5 or higher for a question then the incorrect responses for those questions were tallied to determine if there was a common incorrect response. If a majority of the incorrect responses were the same, then it indicated the likelihood of a misconception being present for that particular concept.

Students were also asked to indicate where they obtained the knowledge that led them to answer the question if they thought they knew the answer. This was done to try to identify where the misconception came from if one appears to exist. Students were asked to list any place they believe they had gained understanding of the information for that question. The answers given by students were then coded into a specific category as follows:

A. School
B. TV, book, internet, etc.
C. Family member
D. On my own
E. I don’t remember

For any question with a Likert rating of 2.5 or greater, the source of the misconception was analyzed to see if there is a common source of the misconception.

The design of this study is what Campbell and Stanley (1963) call a quasi-experiment using a non-equivalent comparison group. The tool was administered prior to
a unit in meteorology, immediately following the treatment, and at the end of the unit where the questions from the tool were built into a unit test. The Likert scale and the description of where the students learned it were omitted from the unit test. The pre-test results were not shared with the students so their post-test answers would not be influenced by what they answered on the pre-test. The results of the post-tests and the post-post tests were compared to the pre-test of students who were identified as having misconceptions. The questions that they answered incorrectly on the pre-test were compared to the same questions on the post-test. An analysis was run on the number of students who overcame the misconception to those who did not. For any students who did not overcome their misconceptions a comparison of their original answers to the new answers was completed. If the original answer was the same as the new answer then the misconception was not overcome and if the new answer was different from the old answer then it would be considered that there is a non-conception instead of a misconception.

**Treatment**

The school district has specific regulations about what needs to be included into the learning environment of the classroom. All classes in the school district require that lessons revolve around a Lesson Essential Question (LEQ). The LEQ should be the focus of the lesson as well as the assessment and is required to be posted in the room during the lesson. The district also requires the use of advanced organizers to help all students in the learning process. Also, the district has strict guidelines requiring all classes of the same subject to have common objectives, LEQ’s, as well as common assessments. In accordance with these guidelines, the students received an advanced
graphic organizer prior to the unit called a Student Learning and Understanding Guide (SLUG) (see appendix D). The SLUG contains the essential questions, skills, and pertinent vocabulary needed for students to successfully understand the unit.

The SLUG contains the four major topics for the Meteorology unit, but the second concept from the unit, the water cycle, was the focus of this study. Understanding how the water cycle works aligns with the national science standards from the Next Generation Science Standards (NGSS) directly and made it a sensible topic to address.

The water cycle is addressed specifically on standard MS-ESS2-4: Earth Systems of the NGSS. It specifically states, “develop a model to describe the cycling of water through Earth’s systems driven by energy from the sun and the force of gravity” (Next Generation Science Standards, 2013). A diagram showing the water cycle as described by the National Oceanic and Atmospheric Administration can be found in Appendix E (National Oceanic and Atmospheric Administration, 2010).

Prior to starting the unit in meteorology, students were all given the misconceptions survey and self-efficacy survey. Students were introduced to the vocabulary for the Meteorology unit first in order to preview and obtain experience with the vocabulary before having to tackle the whole concept. All of the students defined the vocabulary, but more importantly they researched the understanding of the meanings of the words using vocabulary sheets (see Appendix F) that are modified Frayer Diagrams (Dunston & Tyminski, 2013). The students had to explain the meaning of the definitions and describe what the term is like as well as give appropriate examples that relate to the vocabulary word. The essential questions that are on the SLUG define the problem and by completing the vocabulary the student have to ask questions of themselves about what
the definitions mean and define the problem of how the vocabulary assists in answering the LEQ that is associated with that set of vocabulary. This fits into the NGSS model of practices for K-12 classrooms where science students should ask questions and define problems (Next Generation Science Standards, 2013).

Upon completion of the first concept, “Heating of the Atmosphere,” the treatment began on the “Water Cycle” concept. The treatment started with an open discussion about what the students remembered about the water cycle from previous years of education and how it related to what was found on the SLUG. The students completely ran the discussion with the teacher acting as a facilitator to keep the students focused on the water cycle. Then the teacher demonstrated how to find relative humidity and dew point using a sling psychrometer. The teacher left the students with the question of “How does the sling psychrometer work?” after the demonstration was finished.

The sling psychrometer has two thermometers on it; one of them has a cotton cloth on it called a sock. The thermometer with the sock is called the wet bulb and the one without the sock is the dry bulb. The sock is saturated with room temperature water. The sling psychrometer is able to be swung, spinning the two thermometers. This is to be done at a rapid rate for about a minute. The temperature of the wet bulb will show a lower reading than that of the dry bulb due to evaporative cooling unless the air is at 100% relative humidity in which case the wet bulb temperature would be the same as the dry bulb. The difference between the wet and dry bulb can be used to determine the relative humidity and dew point of the air using a Relative Humidity and Dew Point Chart (see Appendix G).
After the demonstration, the students worked in groups to try and answer the question “how does the sling psychrometer work?” A jigsaw activity allowed members from different groups to compare answers from their group to the other groups’ ideas. Afterwards, a whole class discussion allowed the students to express their ideas to the class, with the teacher facilitating the discussion helping the students understand their shortcomings and possible gaps in their thoughts.

Once this extensive introductory activity was complete, the students were introduced to the water cycle project. Students were given the opportunity to pick the path of learning that works best for them. All of the projects have similar requirements but take into account the different interests that individual students may have. They had the choice of four different paths. The first path they could accomplish on their own by writing a story about the life of a water molecule as it moved through the water cycle (path 1) (see Appendix H). The second path allowed groups to work together to write and perform a play for the class about the life of a molecule moving through the water cycle (path 2) (see Appendix H). The third path was an individual or group project where a video/podcast is created that tells the life of a molecule on its journey through the water cycle (path 3) (see Appendix H). The final path is also an individualized or group project that allows students to build a model and explain how the model shows the water cycle at work to the class (path 4) (see Appendix I).

Each of the paths that the treatment groups could use allowed students to research, analyze, and apply the concepts and processes that occur in the water cycle. These activities follow the NGSS practices where students will have to plan and carryout investigations, construct explanations and design solutions, engage in arguments
supported by evidence and being able to communicate information (Next Generation Science Standards, 2013). I designed these activities in order for students to be immersed in a discovery learning environment and kept it as open as I could to give students choices, but narrow enough to make sure the curriculum is covered and the treatment could be accomplished in a reasonable amount of time. By doing this, the students were actively involved in the process of discovery learning as described by Sutman, Schmuckler, and Woodfield (2008). The students were able to develop and practice their investigative skills and they had to answer their own inquiries that arose as they traveled the path they have chosen. All but one of the paths takes into account Dole and Sinatra (1998) ideas of social motivational influences. They states that “interactions with members of a community, school, or peer group may motivate individuals to process information they would not otherwise consider” (p. 120)

Upon completing the treatment lesson, students completed the work for concepts three and four from the SLUG. Once the entire unit was complete the students were given the same unit test. Incorporated into the unit test were the items from the data collection tool used prior to the instruction with the Likert scale left out of the multiple choice questions. After the test students completed the Self-efficacy survey once again.

The comparison group was not exposed to the same teaching strategies as the treatment group. It must be reiterated that the comparison group was covering a complete different content in class than the treatment group. Although both groups were in an 8th grade science class, the comparison group focused on physical science, in particular the structure of the atom and atomic theory, whereas the treatment group was in an earth science class focusing on meteorology. Also, the comparison students were in
a setting that was more traditional: lecture based with a curriculum that follows the content in the textbook. They did incorporate hands-on activities, but these activities were textbook labs that followed closely and replicated the content presented by the teacher during the lecture setting. The comparison group completed the pre-test and the post-test at the same time as the treatment group. They were not given an initial post-test because they did not receive the same content as the treatment group.

Role of the Researcher

As the researcher, I took an active role in implementing the treatment that is described above. Being a seasoned veteran teacher, with extensive science pedagogical training, I wanted to conduct action research on the ideals that I have been trained in throughout my educational history. I was the sole teacher delivering the treatment to all of my students and tried to determine if using discovery learning made an impact on students’ academic performance, self-efficacy in science, and ability to overcome misconceptions that they may have.
CHAPTER 4

RESULTS

This study attempted to answer four main research questions and in this section the results of the study will be presented. First the sample will be described, and then each of the four research questions will be presented along with the data that accompany that question. The four research questions this study investigated are as follows:

1. Does the use of discovery learning – enabling students to develop and practice investigative skills in the search for the answers to their own inquiries – affect students’ understanding of the processes involved in the water cycle?
2. Does the use of discovery learning affect students’ self-efficacy about science?
3. What misconceptions do students have about water in the atmosphere and the processes of the water cycle?
4. What is the origin of a misconception identified by this study?

The final results that will be presented in this section will include how discovery learning affects different academic levels. Although not one of the research questions intended by this study, the differentiation of the students by the school allowed an analysis by academic level.

Sample

The data collected for this study included a pre-test, a post-test, and a post-post test (treatment group only) score for nine different items related to the hydrologic cycle as well as a pre-test and post-test science self-efficacy survey. The data collection tool and self-efficacy survey were given to 82 eighth-grade students (45 females and 37 males), 51 students (33 females and 18 males) were in the treatment group while 31
students (12 females and 19 males) were in the comparison group. The students attended a middle class suburban junior/senior high school that has less than a ten percent minority population. Both the treatment group and comparison group were subdivided by academic level. There were 36 academic students (17 treatment and 19 comparison) and 46 advanced students (36 treatment and 12 comparison). Only 82 students of the 154 eighth-graders that attend the school data were used because either a parental permission slip was not returned or the student did not sign the student assent form.

**Research Question 1.**

**Does the Use of Discovery Learning – Enabling Students to Develop and Practice Investigative Skills in the Search for the Answers to Their Own Inquiries – Affect Students’ Understanding of the Processes Involved in the Water Cycle?**

The first research question called for an analysis between the treatment group and the comparison group to determine if the use of discovery learning had an impact on student learning. A repeated measures ANOVA was computed comparing the pre-test to the post-test for the treatment group against the comparison group. Because the students came from two different academic levels, an additional ANOVA was conducted that included academic level as an additional between students factor.

Before any results are presented, a brief comment about the analysis process might help clarify the results. For a design involving a pre-test and a post-test, there are two possible analyses that can be conducted: a repeated measures ANOVA or an analysis of covariance using the pre-test as the covariate. As long as the groups do not differ at the pre-test, either analysis is appropriate. In the analyses that will be presented in this chapter, the repeated measures approach was chosen because it is typically easier to
understand. In addition, in current usage, all statistical analyses should be followed by a measure of effect size. For ANOVA-based statistics, the statistic that is currently used (and the one provided by SPSS) is partial eta squared. This statistic is equivalent to a correlation squared where a value of .10 or larger corresponds to what Cohen (1968) calls a large effect size.

**ANOVA Results for Pre to Post-test for Treatment vs. Comparison Group**

A repeated measure analysis of variance (ANOVA) was performed on the data collected from the data collection tool for correct answers between the pre-test and post-test responses for both the treatment students and the comparison students to ascertain if there were significant differences gained from the treatment. The same procedure was completed a second time adding gender as a between students factor. Also a repeated measure ANOVA was performed for correct answers between the post-test and the post-post-test for the treatment students to check for a significant change between the two testing periods. Once again the procedure was performed a second time separating it by gender.

The overall means and standard deviations for correct answers on the data collection tool are shown in Table 4.1. Table 4.2 shows the repeated measures ANOVA results for correct answers between the students and within the students.
Table 4.1

*Table of Means and (Standard Deviations) for Correct Answers*

<table>
<thead>
<tr>
<th></th>
<th>Pre-Test</th>
<th>Post-Test</th>
<th>Post-Post-Test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Treatment Group</strong></td>
<td>2.04 (1.13)</td>
<td>3.12 (1.39)</td>
<td>3.69 (1.49)</td>
</tr>
<tr>
<td><strong>Comparison Group</strong></td>
<td>2.16 (1.29)</td>
<td>2.26 (1.46)</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 4.2

*Repeated Measures ANOVA Results for Correct Answers*

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Significance</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Between Students</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group (Treatment vs Comparison)</td>
<td>1</td>
<td>5.244</td>
<td>2.72</td>
<td>.103</td>
<td>.033</td>
</tr>
<tr>
<td>Error Between</td>
<td>80</td>
<td>1.927</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Within Students</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Post</td>
<td>1</td>
<td>13.314</td>
<td>6.788</td>
<td>.004</td>
<td>.099</td>
</tr>
<tr>
<td>Group by Pre-Post</td>
<td>1</td>
<td>9.290</td>
<td>6.132</td>
<td>.015</td>
<td>.071</td>
</tr>
<tr>
<td>Error Within</td>
<td>80</td>
<td>1.515</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results shown in Table 4.2 reveal that there is a significant main effect for pre-post. As shown in Table 4.1, the post-test mean is higher than the pre-test indicating that students increased the number of correct answers from the pre-test to the post-test. More importantly, there is a significant interaction between Group and Pre-Post. Both significant effects are in the medium to large range. The plot of this interaction is shown in Figure 4.1.
The post-hoc results show that the treatment group and the comparison group do not significantly differ at the pre-test \((t = .449, p = .65)\), but they do significantly differ at the post-test \((t = 2.659, p = .009)\). Also identified by the post-hoc results is that the treatment group does significantly improve from pre-test to post-test \((t = 5.063, p = .000)\). Although the comparison group does show a slight improvement, it is not a statistically significant improvement \((t = .262, p = .795)\). The same statistical analysis was run adding gender as an additional between students factor. Neither the main effect for gender nor any of the interactions with gender were significant.

**Research Question 2.**

**Does The Use of Discovery Learning Affect Students’ Self-efficacy about Science?**

The second research question called for an analysis between the treatment group and the comparison group to determine if the use of discovery learning had an impact on
students’ science self-efficacy. A repeated measure ANOVA was performed on the data collected from the self-efficacy survey between the pre-test and post-test responses for both the treatment students and the comparison group to ascertain if there were significant differences gained in self-efficacy from the treatment. The same procedure was performed a second time on the data separating it by gender.

The overall means and standard deviations for self-efficacy from the self-efficacy survey are shown in Table 4.3. Table 4.4 shows the results of the repeated measures ANOVA.

<table>
<thead>
<tr>
<th>Table 4.3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Table of Means and (Standard Deviations) for Self-Efficacy</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Treatment Group</td>
</tr>
<tr>
<td>Comparison Group</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 4.4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Repeated Measures ANOVA Results for Self-Efficacy</strong></td>
</tr>
<tr>
<td>Source</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Between Students</td>
</tr>
<tr>
<td>Group (Treatment vs. Comparison)</td>
</tr>
<tr>
<td>Error Between</td>
</tr>
<tr>
<td>Within Students</td>
</tr>
<tr>
<td>Pre-Post</td>
</tr>
<tr>
<td>Group by Pre-Post</td>
</tr>
<tr>
<td>Error Within</td>
</tr>
</tbody>
</table>
As shown in Table 4.4, none of the terms in the ANOVA were significant indicating that the students did not increase in self-efficacy as a function of the treatment. Similar to the previous results, the subsequent analysis by gender was insignificant.

**ANOVA Results for Confidence Ratings from Pre to Post-test by Group**

Although confidence in answering a question correctly does not specifically show students’ science self-efficacy, how confident they are that their answer is correct can be influenced by their self-efficacy. Therefore a repeated measure ANOVA was performed on the data collected from the data collection tool for the average confidence between the pre-test and post-test responses for both the treatment students and the comparison group to ascertain if there were significant differences gained from the treatment. The overall means and standard deviations for confidence for both the treatment and comparison group on both the pre and post-test are shown in Table 4.5. Table 4.6 presents the results of the repeated measures ANOVA.

<table>
<thead>
<tr>
<th></th>
<th>Pre-Test</th>
<th>Post-Test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Treatment Group</strong></td>
<td>2.51</td>
<td>3.08</td>
</tr>
<tr>
<td></td>
<td>(.468)</td>
<td>(.469)</td>
</tr>
<tr>
<td><strong>Comparison Group</strong></td>
<td>2.64</td>
<td>2.87</td>
</tr>
<tr>
<td></td>
<td>(.432)</td>
<td>(.348)</td>
</tr>
</tbody>
</table>
Table 4.6

Repeated Measures ANOVA Results for Confidence Ratings

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Significance</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Students</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group Treatment vs. Comparison</td>
<td>1</td>
<td>.057</td>
<td>.197</td>
<td>.659</td>
<td>.003</td>
</tr>
<tr>
<td>Error Between</td>
<td>63</td>
<td>.290</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within Students</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Post</td>
<td>1</td>
<td>4.293</td>
<td>38.457</td>
<td>.000</td>
<td>.379</td>
</tr>
<tr>
<td>Group by Pre-Post</td>
<td>1</td>
<td>.738</td>
<td>6.610</td>
<td>.013</td>
<td>.095</td>
</tr>
<tr>
<td>Error Within</td>
<td>63</td>
<td>.112</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results shown in Table 4.6 reveal that the main effect for Pre-Post is significant with a large effect. As shown in Table 4.5, the students increased in confidence between the pre-test and the post-test. In addition, there is significant interaction between Group and Pre-Post with a medium to large effect. The interaction is shown in Figure 4.2.

Figure 4.2: Plot of Pre-Post Confidence Ratings
As shown in Figure 4.2, the treatment group demonstrated a greater gain between the pre-test and the post-test as compared to the comparison group. Additional analyses indicate that the two groups were not significantly different at the pre-test ($t = 1.037, p = .303$), but that they did differ at the post-test ($t = 2.22, p = .029$). In addition, the post-hoc analysis indicated that both groups significantly gained in confidence between the pre-test and the post-test ($t$ (treatment) = 7.23, $p = .000$; $t$ (comparison) = 3.61, $p = .002$). To clarify this analysis further, a simple change score was computed and the two groups were compared on this variable. The average change in confidence for the treatment group was .565 while the average for the comparison group was .234. The difference between these two means is statistically significant ($t = 2.57, p = .002$).

**Further analysis by academic level**

The students in this study were differentiated by academic level allowing an additional question to be analyzed. The extended research question that was asked was “do students in different academic levels demonstrate significantly different changes in knowledge and self-efficacy?”

**ANOVA Results for Pre-test to Post-test Comparing Academic Levels**

The same repeated measure ANOVA was performed on the data collected from the data collection tool for correct answers between the pre-test and post-test responses for both the treatment and the comparison groups combined but separating the students by academic level. Table 4.7 shows the overall means for correct answers for the Academic and Advanced level students on both the pre-test and post-tests. Table 4.8 presents the results of the repeated measures ANOVA.
Table 4.7

*Table of Means and (Standard Deviations) for Correct Answers by Academic Level*

<table>
<thead>
<tr>
<th></th>
<th>Pre-Test</th>
<th>Post-Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic</td>
<td>2.25</td>
<td>2.33</td>
</tr>
<tr>
<td></td>
<td>(1.36)</td>
<td>(1.39)</td>
</tr>
<tr>
<td>Advanced</td>
<td>1.96</td>
<td>3.15</td>
</tr>
<tr>
<td></td>
<td>(1.03)</td>
<td>(1.45)</td>
</tr>
</tbody>
</table>

Table 4.8

*Repeated Measures ANOVA Results for Correct Answers*

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Significance</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Students</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group (Aca vs. Adv)</td>
<td>1</td>
<td>2.787</td>
<td>1.424</td>
<td>.236</td>
<td>.017</td>
</tr>
<tr>
<td>Error Between</td>
<td>80</td>
<td>1.958</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within Students</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Post</td>
<td>1</td>
<td>16.518</td>
<td>11.199</td>
<td>.001</td>
<td>.123</td>
</tr>
<tr>
<td>Group by Pre-Post</td>
<td>1</td>
<td>12.493</td>
<td>8.470</td>
<td>.005</td>
<td>.096</td>
</tr>
<tr>
<td>Error Within</td>
<td>80</td>
<td>1.475</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results shown in Table 4.8 reveal that there is a significant main effect for Pre-Post and a significant interaction, with both demonstrating a large effect. A graph of the interaction is presented in Figure 4.3.
Figure 4.3: Plot of Interaction for Pre to Post Correct Answers by Academic level

The post-hoc analysis for the interaction showed that the students in the advanced level significantly increased from the pre-test to the post-test ($t = 5.16, p = .000$). The academic students, however, did not demonstrate a significant change ($t = .265, p = .793$).

Post-Post Test Results for Treatment Group by Academic Level

The same repeated measure ANOVA was performed on the data collected from the data collection tool for correct answers between the pre-test, post-test and post-post-test responses for the treatment group separating the students by academic level. Table 4.9 shows the overall means for correct answers for the Academic and Advanced level students on all three tests. Table 4.10 shows the repeated measures ANOVA results.
Table 4.9

*Table of Means and (Standard Deviations) for Correct Answers*

<table>
<thead>
<tr>
<th></th>
<th>Pre-Test</th>
<th>Post-Test</th>
<th>Post-Post Test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Academic (N= 17)</strong></td>
<td>2.41</td>
<td>2.76</td>
<td>3.12</td>
</tr>
<tr>
<td></td>
<td>(1.37)</td>
<td>(1.30)</td>
<td>(1.41)</td>
</tr>
<tr>
<td><strong>Advanced (N = 34)</strong></td>
<td>1.85</td>
<td>3.29</td>
<td>3.97</td>
</tr>
<tr>
<td></td>
<td>(.958)</td>
<td>(1.43)</td>
<td>(1.47)</td>
</tr>
</tbody>
</table>

Table 4.10

*Repeated Measures ANOVA Results for Correct Answers*

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Significance</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Between Students</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group (Aca vs. Adv)</td>
<td>1</td>
<td>2.562</td>
<td>.854</td>
<td>.360</td>
<td>.017</td>
</tr>
<tr>
<td>Error Between</td>
<td>49</td>
<td>3.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Within Students</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Post</td>
<td>2</td>
<td>23.141</td>
<td>20.576</td>
<td>.000</td>
<td>.296</td>
</tr>
<tr>
<td>Group by Pre-Post</td>
<td>2</td>
<td>6.199</td>
<td>5.512</td>
<td>.005</td>
<td>.101</td>
</tr>
<tr>
<td>Error Within</td>
<td>98</td>
<td>1.125</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results shown in Table 4.10 reveal that there is a significant main effect for pre-post and a significant interaction. As shown in Figure 4.4 both groups increased the number of correct answers between the pre-test and the post-test with the students in the advanced courses increasing at a higher rate.
Figure 4.4: Plot of Interaction for Pre to Post-post Correct Answers by Academic level

ANOVA Result for Self-efficacy by Academic Level

An identical analysis to the repeated measures ANOVA described above was conducted but in this case using the self-efficacy data. The means for self-efficacy by academic level are shown in Table 4.11. Table 4.12 shows the repeated measures ANOVA results.

<table>
<thead>
<tr>
<th>Table 4.11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table of Means and (Standard Deviations) for Self-efficacy</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Academic</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Advanced</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
Table 4.12

Repeated Measures ANOVA Results for Self-efficacy

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Significance</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Students</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group (Aca vs Advl)</td>
<td>1</td>
<td>5.134</td>
<td>9.301</td>
<td>.003</td>
<td>.108</td>
</tr>
<tr>
<td>Error Between</td>
<td>77</td>
<td>.552</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within Students</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Post</td>
<td>1</td>
<td>.042</td>
<td>.621</td>
<td>.433</td>
<td>.008</td>
</tr>
<tr>
<td>Group by Pre-Post</td>
<td>1</td>
<td>.204</td>
<td>3.022</td>
<td>.086</td>
<td>.038</td>
</tr>
<tr>
<td>Error Within</td>
<td>80</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

According to the results of shown in Table 4.12, the only significant effect is between the two types of students with students in the advanced course performing at a higher rate.

**Research Question 3**

**What Misconceptions do Students Have about Water in the Atmosphere and The Processes of the Water Cycle?**

To answer the third research question each student was given the data collection tool with the confidence rating system that was described in Chapter 3. To look for common misconceptions, the confidence levels were averaged, and any questions that had a majority of incorrect responses plus a confidence rating of 2.5 or higher were judged to be possible misconceptions. A z-test was then completed comparing the responses on each of the items to see if any incorrect response had a significant number of responders. A Pearson correlation was run on each item from the data collection tool for both the pre and post-test to see if there was a correlation between picking the wrong answer and how confident students were in picking the incorrect answer. This was
completed to help narrow down specific misconceptions. The results of the analysis are described in the following sections.

**Breakdown of Confidence Ratings of the Pre and Post-test for Both Groups**

The average confidence rating for each of the nine items from the data collection tool were examined for the combined average of both the treatment and the comparison groups on the pre-test as well as the post-test. This was completed in order to determine if choices made by the students were more likely guesses or answers that they believe to be true. The average confidence rating was calculated for each question with the cutoff for the confidence ratings set at 2.5. Any questions that had an average confidence rating smaller than 2.5 would be considered guesses at answers rather than overall beliefs that the answer selected were true. Whereas confidence ratings of 2.5 or higher would be considered selections that the students held to be true.

The individual items from the data collection tool were also analyzed to determine the total number of individuals who selected each choice for each of the items on the pre-test and also on the post-test. Once the totals were calculated, a comparison was done for each choice for each particular item to determine if the totals for incorrect choices were greater than the total for the correct choice. Table 4.13 shows the item breakdown of the confidence rating for both the pre and post-test as well as if any incorrect choice totaled higher than the correct choice for each item.
In Table 4.13 it is shown that the pre-test items 1, 3, 4, and 5 have confidence ratings of 2.5 or higher as well as having incorrect answers that outnumber correct responses. The same is also true on the post-test for items 1, 2, 3, 4, 5, 7, and 8.

*z-test for Proportions for Individual Item Responses on the Pre-test*

All the items that were identified by the previous criteria were individually subjected to a z-test for proportions to determine if any of the incorrect answers selected by the students were significantly greater than that of the other choices offered to them by the item. To run the z-test, an online statistical z-test for proportions calculator was used (McCallumLayton, 2013). The statistical significance level was set at $p = .05$ on all z-test for proportion tests that were calculated.

The four items identified on the pre-test (items 1, 3, 4, and 5) were subjected to the z-test for proportions. Figure 4.6, Item 1 Pre-test All, shows the choice totals for each choice to item 1 on the pre-test for all the students combined (the correct answer is designated by an asterisk (*)). Figure 4.5 clearly shows that more students, 90%, chose
A over all the other choices. The z-test confirmed that significantly more individuals chose A over any of the other choices.

![Graph for Item 1 Pre-test All](image)

*Figure 4.5:* Graph for Item 1 Pre-test All

Similar results were calculated for responses to items 3, 4, and 5 on the pre-test. For item 3, 64% of students, chose D over all the other choices. The z-test confirmed that significantly more individuals chose D over any of the other choices. Likewise, for item 4, 51%, chose B over all the other choices with the z-test confirming that significantly more individuals chose B over any of the other choices. Finally for item 5, 81%, chose A over all the other choices. The z-test confirmed that significantly more individuals chose A over any of the other choices.
**z-test for Proportions for Individual Item Responses on the Post-test**

Like the items from the pre-test, the seven items identified on the post-test (items 1, 3, 4, 5, 7, and 8) which met the given criteria were each subjected to the z-test for proportions. Figure 4.6, Item 1 Post-test All, shows the choice totals for each choice to item 1 on the post-test for all the students combined (the correct answer is designated by an asterisk (*)). Figure 4.6 clearly shows that more students, 87%, chose A over all the other choices. The z-test confirmed that significantly more individuals chose A over any of the other choices.

![Figure 4.6: Graph for Item 1 Post-test All](image)

Similar results were calculated for responses to items 5, 7, and 8 on the post-test. The responses for item 5 showed that 67% of the students chose A over all the other choices. The z-test confirmed that significantly more individuals chose A over any of the
other choices. Also the results for item 7 showed 53% of students chose D over all the other choices. The z-test confirmed that significantly more individuals chose D over any of the other choices. Lastly on item 8, 82% of the students chose A over choice B. The z-test confirmed that significantly more individuals chose A over B.

On the post-test, the results for item 3 and item 4 were not as definitive. Figure 4.8, Item 3 Post-test All, shows the choice totals for each choice to item 3 on the pre-test for all the students combined. Figure 4.7 shows that 40% of the students chose D over all the other choices. The z-test confirmed that significantly more individuals chose D over choices B (13%) and C (19%), but the difference between choice D and choice A (28%) was not significant.

![Graph for Item 3 Post-test All](image)

*Figure 4.7: Graph for Item 3 Post-test All*

Similar to item 3, item 4 results showed that only 38% of students chose B over all the other choices. The z-test confirmed that significantly more individuals chose B
over choice C (9%), but the difference between choice B and choices A (30%) and D (22%) were not significant.

**Item Results Breakdown Pre, Post and Post-post-test for Treatment Group**

The average confidence rating for each of the nine items from the data collection tool were examined for the treatment group on the pre-test as well as the post-test. This was completed in order to determine if choices made by the treatment group students were more likely guesses or answers that they believe to be true. The average confidence rating was calculated for each question with the cutoff for the confidence ratings set at 2.5. Any questions that had an average confidence rating smaller than 2.5 would be considered guesses at answers rather than overall beliefs that the answer selected were true. Whereas confidence ratings of 2.5 or higher would be considered selections that the students held to be true.

The individual items from the data collection tool were also analyzed to determine the total number of individuals that selected each choice for each of the items. This was completed for the pre-test, post-test, and the post-post test. Once the totals were calculated, a comparison was done for each choice for each particular item to determine if the totals for incorrect choices were greater than the total for the correct choice. Although the post-post test for the treatment group did not have a confidence rating, the totals of responses to choices could still be calculated. Table 4.14 shows the item breakdown of the confidence rating for both the pre and post-test as well as if any incorrect choice totaled higher than the correct choice for each item. Also included in table 4.14 are the results for the post-post test analysis if any incorrect choice totaled higher than the correct choice for each item.
Table 4.14

**EXP Item Breakdown for CR Pre & Post**

<table>
<thead>
<tr>
<th>Item</th>
<th>Pre-test CR</th>
<th>Incorrect Choice</th>
<th>Post-test CR</th>
<th>Incorrect Choice</th>
<th>Post-post</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.4*</td>
<td>Yes*</td>
<td>3.5*</td>
<td>Yes*</td>
<td>Yes*</td>
</tr>
<tr>
<td>2</td>
<td>1.3</td>
<td>Yes</td>
<td>2.7*</td>
<td>Yes*</td>
<td>Yes*</td>
</tr>
<tr>
<td>3</td>
<td>2.8*</td>
<td>Yes*</td>
<td>2.7</td>
<td>Yes*</td>
<td>Yes*</td>
</tr>
<tr>
<td>4</td>
<td>2.4</td>
<td>Yes</td>
<td>3.0*</td>
<td>Yes*</td>
<td>Yes*</td>
</tr>
<tr>
<td>5</td>
<td>3.4*</td>
<td>Yes*</td>
<td>3.6*</td>
<td>Yes*</td>
<td>Yes*</td>
</tr>
<tr>
<td>6</td>
<td>2.6</td>
<td></td>
<td>3.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>2.0</td>
<td>Yes</td>
<td>2.8*</td>
<td>Yes*</td>
<td>Yes*</td>
</tr>
<tr>
<td>8</td>
<td>2.2</td>
<td>Yes</td>
<td>2.9*</td>
<td>Yes*</td>
<td>Yes*</td>
</tr>
<tr>
<td>9</td>
<td>2.2</td>
<td></td>
<td>3.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Meet criteria

In Table 4.14 it is shown that for the pre-test items 1, 3, and 5 have confidence ratings of 2.5 or higher as well as having incorrect answers that outnumber correct responses. The same is also true on the post-test for items 1, 2, 4, 5, 7, and 8. It is also shown in table 4.2 that on the post-post-test items 1, 2, 4, 5, 7, and 8 had incorrect answers that outnumber correct responses that mirror the post-test results.

**z-test for Proportions for Individual Item Responses: Pre-test Treatment Group**

All the items that were identified by the previous criteria were individually subjected to a z-test for proportions to determine if any of the incorrect answers selected by the students were significantly greater than that of the other choices offered to them by the item. To run the z-test, an online statistical z-test for proportions calculator was used (McCallumLayton, 2013). The statistical significance level was set at $p = .05$ on all z-test for proportion tests that were calculated.
The three items identified on the pre-test (items 1, 3, and 5) were subjected to the z-test for proportions. Figure 4.8, Item 1 Pre-test Exp Group, shows the choice totals for each choice to item 1 on the pre-test for the treatment group (the correct answer is designated by an asterisk (*)). Figure 4.8 clearly shows that more students, 90%, chose A over all the other choices. The z-test confirmed that significantly more individuals chose A over any of the other choices.

![Figure 4.8: Graph for Item 1 Pre-test Exp Group](image)

The data for items 3 and 5 showed similar outcomes. The results for item 3 showed that 63% of students chose D over all the other choices. The z-test confirmed that significantly more individuals chose D over any of the other choices. Likewise the results for item 5 concluded that 84% of students chose A over all the other choices. The z-test confirmed that significantly more individuals chose A over any of the other choices.
z-test for Proportions for Individual Item Responses: Post-test Treatment Group

Like the items from the pre-test, the six items identified on the post-test (items 1, 2, 4, 5, 7, and 8) which met the given criteria were each subjected to the z-test for proportions. Figure 4.9, Item 1 Post-test Exp Group, shows the choice totals for each choice to item 1 on the post-test for the treatment group (the correct answer is designated by an asterisk (*)). Figure 4.9 clearly shows that more students, 71%, chose A over all the other choices. The z-test confirmed that significantly more individuals chose A over any of the other choices.

![Graph for Item 1 Post-test Exp Group](image)

*Figure 4.9: Graph for Item 1 Post-test Exp Group*

The data for items 7 and 8 showed similar outcomes. The results for item 7 shows that more students (60%) chose D over all the other choices. The z-test confirmed that significantly more individuals chose D over any of the other choices. Likewise the results for item 8 shows that more students (81%) chose A over choice B. The z-test confirmed that significantly more individuals chose A over B.
Although item 5 showed a significant incorrect response, it was not significant over all of the other choices. Figure 4.11, Item 5 Post-test Exp Group, shows the choice totals for each choice to item 5 on the post-test for the treatment group. Figure 4.10 clearly shows that more students, 56%, chose A over all the other choices. The z-test confirmed that significantly more individuals chose A over choices B (6%) and D (6%), but the difference between A and C (31%) was not significant.

![Item 5 Post-test Exp Group](image)

*Figure 4.10: Graph for Item 5 Post-test Exp Group*

Even less definitive were the results calculated to items 2 and 4. They both showed that one of the incorrect choices was significant over the correct, but it was not significant over the other two incorrect choices. Figure 4.11, Item 2 Post-test Exp Group, shows the choice totals for each choice to item 2 on the post-test for the treatment group. Figure 4.11 shows that more students, 45%, chose A over all the other choices. The z-
test confirmed that significantly more individuals chose A over choice D (4%), but the difference between choices B (31%) and C (20%) to A were not significant.

A similar result was calculated for the responses to item 4. The data showed that 45% of the students chose B over all the other choices. The z-test confirmed that significantly more individuals chose B over choice C (12%), but the difference between choice B and choices A (25%) and D (18%) were not significant.

z-test for Proportions for Individual Item Responses: Post-post-test Treatment Group

Like the items from the pre-test and the post-test for the treatment group, six items identified on the post-post-test (items 1, 2, 4, 5, 7, and 8) met the given criteria for incorrect responses outnumbering the correct response. There was no confidence rating on the post-post-test so this was the only criterion used to run the z-test for proportions. Figure 4.13, Item 2 Post-post-test Exp Group, shows the choice totals for each choice to
item 2 on the post-post-test for the treatment group (the correct answer is designated by an asterisk (*)). Figure 4.12 shows the choice totals for each choice to item 2 on the post-post-test for the treatment group. Figure 4.12 shows that more students, 60%, chose A over all the other choices. The z-test confirmed that significantly more individuals chose A over any of the other choices.

![Graph for Item 2 Post-test Exp Group](image)

*Figure 4.12: Graph for Item 2 Post-test Exp Group*

The data for items 4 and 8 showed similar outcomes. Results for item 4 show that more students, 60%, chose B over all the other choices. The z-test confirmed that significantly more individuals chose B over all of the other choices. Likewise the results for item 8 show that more students, 86%, chose A over choice B. The z-test confirmed that significantly more individuals chose A over B.
Although items 1, 5, and 7 showed a significant incorrect response, it was not significant over all of the other choices. As seen in Figure 4.13 for the responses to item 1, the results show that more students, 64%, chose A over all the other choices. The z-test confirmed that significantly more individuals chose A over choices B (2%) and C (0%), but the number of responses for A did not significantly outnumber choice D (34%) which was the correct choice.

![Graph for Item 1 Post-post-test Exp Group](image)

*Figure 4.13: Graph for Item 1 Post-post-test Exp Group*

The data for items 5 and 7 showed similar outcomes. The results for item 5 show that 60% of the responders chose A over all the other choices. The z-test confirmed that significantly more individuals chose A over choices B (0%) and D (6%), but the difference between A and C (34%) was not significant. Similarly the results for number 7 showed that 52% of the students chose D over all the other choices. The z-test confirmed that significantly more individuals chose D over choices B (8%) and C (10%), but the difference between D and A (30%) was not significant.
Pearson Correlation for Correctness and Student Confidence Pre and Post-test

Pearson correlations were computed on the data collected from the data collection tool for each of the nine items on the tool to identify if any correlation exists between being correct on a specific item and the test students’ confidence in their answers on that item. This was completed individually for each item for both the treatment and comparison groups combined for the pre-test and the post-test. The results for each item on the data collection tool for both the pre-test and post-test are shown in Table 4.15.

<table>
<thead>
<tr>
<th>Problem</th>
<th>Pre</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-.231*</td>
<td>.086</td>
<td>.059</td>
<td>.002</td>
<td>-.107</td>
<td>.179</td>
<td>.033</td>
<td>-.275*</td>
<td>-.166</td>
</tr>
<tr>
<td>2</td>
<td>- .124</td>
<td>-.088</td>
<td>.041</td>
<td>.058</td>
<td>.341**</td>
<td>.392**</td>
<td>-.083</td>
<td>-.275*</td>
<td>-.167</td>
</tr>
</tbody>
</table>

*P < .05; **p < .01

The analysis shows that for the pre-test there is a significant correlation for items 1 (.231) and 8 (.275). The negative correlations indicate that students had high confidence for answering the items incorrectly. Item 1 was identified previously as having a possible misconception and the Pearson Correlation helps to confirm the likelihood of there being a misconception in item 1. On the post-test there are three significant items; 5 (.341), 6 (.392), and 8 (.275). On the z-test preformed in the previous section, item 8 showed a possible misconception and the Pearson Correlation supports the finding. Also for item 8 the same outcome is recorded as for the pre-test, but for items 5 and 6 the opposite outcome is true. That is, for items 5 and 6 on the post-test
the positive correlations indicate that students are more confident about the items they answered correctly.

**Pearson Correlation for Correctness and Student Confidence Post-test by Group**

Similarly, Pearson correlations were computed on the data collected from the data collection tool for each of the nine items on the tool to identify if any correlation exists between being correct on a specific item and the test students’ confidence in their answers on that item. This was completed for each item for both the treatment and comparison groups individually for the post-test. The results for each item on the data collection tool for both the treatment and comparison groups are shown in Table 4.16.

<table>
<thead>
<tr>
<th>Table 4.16</th>
<th>Correlations between Correctness and Confidence- Post-Test only for Treatment and Comparison Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Problem 1</td>
</tr>
<tr>
<td>Treatment</td>
<td>-.333*</td>
</tr>
<tr>
<td>Comparison</td>
<td>-.064</td>
</tr>
</tbody>
</table>

*p < .05; **p < .01

The analysis shows that for the treatment group there is a significant correlation for items 1 (-.333), 5 (.418), 6 (.312), and 8 (-.424). The negative correlation on items 1 and 8 show the treatment group had a high confidence for answering the items incorrectly which supports the findings from the z-test that suggest there is a substantial possibility that there is a common misconception found for the treatment group. The positive
correlation on items 5 and 6 show they had high confidence in answering them correctly. For the comparison group there is only one significant item, item 6 (.441). The positive correlation for item 6 from the comparison group shows they were also confident in answering the item correctly.

Research Question 4

What Is the Origin of a Misconception Identified by this Study?

Source of Acquired Misconception

The data collection tool included a question asking the students to try and recall where they may have learned the information to answer the item. The students’ responses were then classified into one of five categories: 1= School; 2= TV, book other than textbook, internet, any other media outlet; 3=family member or friend; 4=student figured it out on his/her own; and 5=student did not know where he/she learned it. If students indicated they learned it from multiple sources than their tally would be added to the first source indicated. If a student did not give any source location for any of the items, then it was assumed the individual forgot to complete that part of the survey and his/her non-responses were not included in the totals. By cross-referencing the results from the data collection tool in the previous section to the items that point to a misconception a possible origin to those misconceptions can be seen. Table 4.17, Tally of Reported Source Learning Areas for Individual Items Pre-test, shows the total responses for each question and response given by both groups on the pre-test. The table also shows the content that each item covered and highlights the possibility of a misconception on the specific items that were confirmed on the z-tests.
Table 4.17

*Tally of Reported Source Learning Areas for Individual Items Pre-test.*

<table>
<thead>
<tr>
<th>Itema</th>
<th>Item choice</th>
<th>School</th>
<th>Media, TV, Internet, Books, Etc.</th>
<th>Family/Friend</th>
<th>Own</th>
<th>Don’t Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cloud composition</td>
<td>A</td>
<td>63</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>69</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2. Heat and water vapor</td>
<td>A</td>
<td>11</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>B</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>9</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>33</td>
<td>0</td>
</tr>
<tr>
<td>3. Evaporating water</td>
<td>A</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>7</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>17</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>19</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>37</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td>4. Frost formation</td>
<td>A</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>B</td>
<td>17</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>31</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>5. Shape of raindrops</td>
<td>A</td>
<td>12</td>
<td>21</td>
<td>0</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
<td>22</td>
<td>1</td>
<td>15</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>6. Cloud formation</td>
<td>A</td>
<td>30</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>23</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 4.17

Continued

<table>
<thead>
<tr>
<th>Itema</th>
<th>Item choice</th>
<th>School</th>
<th>Media, TV, Internet, Books, Etc.</th>
<th>Family/Friend</th>
<th>Own</th>
<th>Don’t Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Water molecules during evaporation</td>
<td>A</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>18</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>27</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>28</td>
</tr>
<tr>
<td>8. Density of moist and dry air</td>
<td>A</td>
<td>16</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>20</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>35</td>
</tr>
<tr>
<td>9. Condensation and relative humidity</td>
<td>A</td>
<td>10</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>8</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>22</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>30</td>
</tr>
</tbody>
</table>

The correct answer for each item is in Bold

a The concept contained in each item is stated in the item column.

Italicized items are z-test confirmed single item for possible misconception.

For item number one, the z-test reported that response A may be a misconception. According to the data, if a misconception does exist about cloud composition, then students may have acquired this misconception from the school environment. On items three and four, there were high numbers of students that could not recall where they had learned the information, but for the students that did recall learning about frost and evaporation they may have picked up the misconceptions in school as well. Item number five that deals with the shape of a raindrop, shows that the misconception may have been ingrained outside of school through TV or other media.
Table 4.18, Tally of Reported Source Learning Areas for Individual Items Post-test, shows the total responses for each question and response given by both groups on the post-test. The table also shows the content that each item covered and highlights the possibility of a misconception on the specific items that were confirmed on the z-tests.

Table 4.18

Tally of Reported Source Learning Areas for Individual Items on Post-test.

<table>
<thead>
<tr>
<th>Itema</th>
<th>Item choice</th>
<th>School</th>
<th>Media, TV, Internet, Books, Etc.</th>
<th>Family/ Friend</th>
<th>Own</th>
<th>Don’t Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cloud composition</td>
<td>A</td>
<td>50</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>64</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2. Heat and water vapor</td>
<td>A</td>
<td>15</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>22</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>3. Evaporating water</td>
<td>A</td>
<td>11</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>4. Frost formation</td>
<td>A</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>27</td>
<td>0</td>
<td>3</td>
<td>4</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>5. Shape of raindrops</td>
<td>A</td>
<td>10</td>
<td>13</td>
<td>1</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>3</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
<td>20</td>
<td>1</td>
<td>14</td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>
Table 4.18

Continued

<table>
<thead>
<tr>
<th>Item a</th>
<th>Item choice</th>
<th>School</th>
<th>Media, TV, Internet, Books, Etc.</th>
<th>Family/Friend</th>
<th>Own</th>
<th>Don’t Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Cloud formation</td>
<td>(A)</td>
<td>27</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>(B)</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>(C)</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>30</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>22</td>
</tr>
<tr>
<td>7. Water molecules during evaporation</td>
<td>(A)</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>(B)</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>(C)</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>(D)</td>
<td>14</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>25</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>28</td>
</tr>
<tr>
<td>8. Density of moist and dry air</td>
<td>(A)</td>
<td>16</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>(B)</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>18</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>35</td>
</tr>
<tr>
<td>9. Condensation and relative humidity</td>
<td>(A)</td>
<td>9</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>(B)</td>
<td>7</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>(C)</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>(D)</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>21</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>29</td>
</tr>
</tbody>
</table>

The correct answer for each item is in **Bold**

*The concept contained in each item is stated in the item column. Italicized items are z-test confirmed single item for possible misconception.*

On the post-test a few new misconceptions show up in items seven, evaporating water, and eight, density of moist and dry air. Both of these misconceptions seem to have been acquired at school.

Table 4.19, Tally of Reported Source Learning Areas for Individual Items Post-post-test, shows the total responses for each question and response given by the treatment group on the post-post-test but since the comparison group was not given the post-post-
test their results were unavailable. The table also shows the content that each item
covered and highlights the possibility of a misconception on the specific items that were
confirmed on the z-tests.

<table>
<thead>
<tr>
<th>Itema</th>
<th>Item choice</th>
<th>School</th>
<th>Media, TV, Internet, Books, Etc.</th>
<th>Family/Friend</th>
<th>Own</th>
<th>Don’t Know</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1. Cloud composition</td>
<td>A</td>
<td>31</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>18</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>49</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>9</td>
<td>0</td>
<td>1</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>29</td>
</tr>
<tr>
<td>2. Heat and water vapor</td>
<td>A</td>
<td>12</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>25</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>19</td>
</tr>
<tr>
<td>3. Evaporating water</td>
<td>A</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>11</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>18</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>22</td>
</tr>
<tr>
<td>4. Frost formation</td>
<td>A</td>
<td>6</td>
<td>13</td>
<td>1</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>4</td>
<td>6</td>
<td>0</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>10</td>
<td>19</td>
<td>1</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>5. Shape of raindrops</td>
<td>A</td>
<td>20</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>22</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>19</td>
</tr>
</tbody>
</table>
Table 4.19
Continued

<table>
<thead>
<tr>
<th>Item</th>
<th>Item choice</th>
<th>School</th>
<th>Media, TV, Internet, Books, Etc.</th>
<th>Family/Friend</th>
<th>Own</th>
<th>Don’t Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Water molecules during evaporation</td>
<td>A</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>11</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>17</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>24</td>
</tr>
<tr>
<td>8. Density of moist and dry air</td>
<td>A</td>
<td>10</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>12</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>27</td>
</tr>
<tr>
<td>9. Condensation and relative humidity</td>
<td>A</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>13</td>
<td>3</td>
<td>4</td>
<td>0</td>
<td>26</td>
</tr>
</tbody>
</table>

The correct answer for each item is in **Bold**

*The concept contained in each item is stated in the item column.

Italicized items are z-test confirmed single item for possible misconception.*

Table 4.19 shows that some of the misconceptions from before still persist, items one, five, seven and eight while an original misconception resurfaces in item four. A new misconception shows up in item number two about heat and water vapor. According to the data for those who remember when they acquired the misconception, they learned it in school.

**Summary of Results**

The analyses completed in this study suggest results for each of the four major research questions that were presented for the study. The first and second research question involve the use of discovery learning in the classroom. The data suggest that
discovery learning may have led to students’ increased knowledge from the pre-test to the post-test. In addition, while both groups of students showed increased confidence in their answers from the pre-test to the post-test, the increase was more pronounced for the students in the treatment group. It was also shown the students in an advanced level demonstrated greater increases in both knowledge and confidence as compared to students in the academic level. The results also indicated, however, that the treatment did not affect science self-efficacy.

In accordance with the third research question, six of the nine items, items 1, 3, 4, 5, 7, and 8, on the data collection tool suggest that a misconception may be present in a significant number of the students. Using the results from question three to help answer research question 4, most of the apparent misconception may have originated in school prior to the students starting their eighth grade year. Although school was sited for the origin to the misconception in item number 5 on the data collection tool, a significant number of students suggest that other media such as books or TV may have created the misconception.
CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This action research study involved 82 junior high school students enrolled in eighth grade earth science and physical science classes. The earth science students were the treatment group that underwent a lesson in discovery learning that included specific content on the water cycle, while the physical science students were the comparison group that were not subjected to discovery learning or the water cycle content. Both groups were subjected to a pre-test of a nine questions multiple choice survey about concepts involving the water cycle. Each item from the survey had a confidence scale in order for students to rate themselves on how confident they were in their answer plus a section asking where they thought they learned the information to answer the question. Both groups also took a pre-test self-efficacy survey containing eight items. Immediately following the treatment group’s instructional sequence, both groups were given the two surveys once again. Finally at the end of the unit for meteorology the treatment group answered the same nine items except this time the questions were built into the unit test.

I taught all four of the treatment classes, two academic and two advanced level earth science classes. But the researcher did not teach the other three remaining classes of two academic and one advanced level physical science classes.

The specific research questions raised in this research related to discovery learning and misconceptions were:
1. How does a teacher’s allowing students to engage in discovery learning—enabling students to develop and practice many investigative skills in the search for the answers to their own inquiries—affect students’ understanding of the processes involved in the water cycle?

2. How does a teacher’s allowing students to engage in discovery learning affect students’ self-efficacy about science?

3. What misconceptions do students have about water in the atmosphere and the processes of the water cycle?

4. What is the origin of a misconception identified by this study?

This study attempted to identify misconceptions that students had about aspects of the water cycle and their possible origin. It also attempted to ascertain the impact that discovery learning had on students’ understanding of the water cycle as well as their self-efficacy in science.

A Pearson correlation analysis was run on both groups for students’ confidence levels and if they were correct on the data collection tool items for each item for both the pre-test and the post-test. The correlation analysis was run a second time for the treatment group breaking it down by academic levels. Using the overall confidence ratings of the students, an ANOVA was calculated for the pre-test to post-test based on the groups.
In order to identify misconceptions, a z-test for proportions was run on any question that had an average confidence rating of 2.5 or higher and had an incorrect response with the highest number of responses. The z-test was completed for all the students for the pre-test, and just the treatment group on the post-test and the post-post test.

The data collected from the data collection tool were analyzed through the use of a repeated measure analysis of variance (ANOVA) for correct answers between the pre-test and post-test responses for both the test students and the comparison group to ascertain if there were significant differences gained from the treatment. An ANOVA was also completed on the pre-test and post-test responses on the self-efficacy survey. Both analyses were calculated for the data collection tool and the self-efficacy survey by separating the groups into their academic levels.

**Discussion of Conclusions**

Each of the research questions identified above is responded to in the following paragraphs.

Research question 1. How does a teacher’s allowing students to engage in discovery learning—enabling students to develop and practice many investigative skills in the search for the answers to their own inquiries—affect students’ understanding of the processes involved in the water cycle?

Based on the ANOVA results, the treatment group had a statistically significant greater gain from the pre-test to the post-test than did the comparison group. This suggests that a discovery learning environment may allow students to gain knowledge
and understanding about the water cycle. This would be expected based on the studies of Guzetti, Snyder, Glass, and Gamas (1993), and Gurses, Acikyildiz, Dogar, and Sozbilir (2007), which obtained similar results of, increased academic performance while using classroom methods that resemble discovery learning. The results in this study show that the gain was not the same for all academic levels of students. They suggest that discovery learning has a greater impact on gaining knowledge and understanding of the water cycle on the advanced students. The same results are true for the longevity of the understanding. Although both the academic and advanced groups gained once again on the post-post-test, the advanced students’ gains were more significant than the academic group gains.

Based on the correlation test results, there are a few questions from the data collection tool that show signs of misconceptions being overcome. The items are 1, 3, 5, and 7. What is shown in the treatment group is that by the time of the post-post-test the original misconception answer is not chosen significantly more over the correct answer. Chan et al. (1997) likewise showed similar finding using a discovery learning environment. In item 1 the pre-test and the post-test show the misconception, but on the post-post-test even though choice A had the majority of the responses the difference between choice A, the misconception, and choice D, the correct answer is not significant. This shows that at least some students were able to change their ideas about what clouds are made of by being subjected to a discovery learning environment.

For item 3 on the test the results show a greater change. On the pre-test the treatment group significantly chose D- the misconception -over the correct answer A. On the post-test more students in the treatment group chose A over D, but it was not a
significant difference. The post-post-test showed a gain on choice A and a decrease on choice D. So it showed that some students were able to overcome their previous ideas about how and why water evaporates.

A similar result is shown for item 5. Although on the pre-test choice A - the misconception - was significantly chosen more than any other response, the post-test and post-post-test show that in the treatment group students chose C - the correct answer - enough to make the number of responses not significantly different from the misconception. Likewise on the latter test students who answered it correctly had a significantly higher confidence rating than students who answered it incorrectly. Therefore, some students were able to fix their misconception about the shape of raindrops.

Item 7 showed a small change from the pre-test to the post-post-test. On both the pre-test, and the post-test Choice D – the misconception - was significantly favored. By the time the post-post-test was given enough of the treatment group was able to correct their misconceptions so that response D was not significantly chosen more than the correct answer A. Therefore, some students were able to overcome their misconception about what happens to water when it becomes to vapor.

Although the results from the study suggest that there was a significant gain after the treatment was completed, the overall gain may not allow students to be proficient on high-stake standardized test. The treatment group went from an original mean of 2.04 on the pre-test to a mean of 3.12 on the post-test to finally a mean of 3.69 on the post-post-test. These numbers translate to a 22.67%, 34.67%, and 42% respectively as percentages on a test. So the average mean went from 22.67% to 42%, which would not allow any
student to pass a classroom test or possible would not produce proficient scores on a standardized test. A possible interpretation of this, is that many of the misconception that were identified in this study were not overcome by a majority of the students and my have hindered students in their ability to fully understand the content and processes covered by the tool used in this study just as Trumper’s (2001) study suggested. Another possible interpretation could be like that of Bar’s (1989) study where he suggested that students held onto the misconception because they created new incorrect supporting ideas for it that made it plausible for them.

An interesting outcome noted in this study was the academic change from the post-test to the post-post-test. One would expect a slight decline in the mean of scores from a post-test to a post-post-test. In this study it was found that the mean actually rose from post-test to post-post-test. This held true for both the academic classes as well as the advanced classes. In fact the academic classes had a greater gain from the post-test to the post-post-test. Students were never given the correct answers to the items until after the post-post-test so they were not “taught” the correct answer after making a mistake. One possible cause for this could be that the items for the post-post-test were built into a unit test and studying for the test helped raise the means. Another possible factor could be an intrinsic motivation to want to find the answers on their own because they did not know the answers. Dole and Sinatra (1998) suggest that when students become motivated they are more likely to have conceptual change, and an intrinsic motivation to learn may be part of it.
Research question 2. How does a teacher’s allowing students to engage in discovery learning affect students’ self-efficacy about science?

The ANOVA results for this study showed that there was no significant change in self-efficacy for either the comparison group or the treatment group based on the responses given. These results are in contrast to what Hsieh et al. (2008) showed in their study where students self-efficacy increased and Akcay et al. (2010) showed in their study where students confidence increased. Both of these studies used a similar classroom environment as this current study’s. Although there was no gain in self-efficacy, the ANOVA results did show there was a significant gain in the confidence in answering questions for the treatment group over the comparison group. This significance shows up in the Pearson correlation results on correctness and student confidence. One item in particular, item 5, shows that students’ confidence in the treatment groups’ confidence on the post-test were significantly higher when they answered the question correctly. Even though self-efficacy and confidence in answering questions is not the same, it can be said that since confidence is part of self-efficacy that some increase may have occurred, but overall however, the increase was too content specific which did not lead to an overall gain in self-efficacy.

Research question 3. What misconceptions do students have about water in the atmosphere and the processes of the water cycle?
Based on the correlation test results, there are a few questions from the data collection tool that show signs of identifying misconceptions. Items 1 and 8 from the tool show the most statistical evidence toward misconceptions. Question 1 is as follows:

1. When you look at a cloud you are looking at:
   A. Water vapor
   B. Smoke
   C. Steam
   D. Liquid water and/or ice

The correct answer for this item is D (liquid water and/or ice). For every scenario tested, choice A (water vapor) was significantly chosen more than any other choices except on the post-post-test for the treatment group. It was also determined that on the pre-test for all students, and the post-test for the treatment group that students who chose the incorrect response were more confident than students who chose the correct response. The results, therefore, suggest that students may have a misconception that clouds are made of water vapor instead of liquid water or ice.

Similar results were found for item 8 from the data collection tool. Question 8 is as follows:

8. Which of the following would be more dense at sea level and at 15°C?
   A. Moist air
   B. Dry air
The correct answer for this item is B (dry air). For every scenario tested, choice A (moist air) was significantly chosen more than choice B. Although on the pre-test for all students question 8 did not reach the confidence rating cutoff of 2.5, still A was chosen more than B. It was also determined that on the pre-test and post-test for all students, and the post-test for the treatment group that students who chose the incorrect response were more confident than students who chose the correct response. The results, therefore, suggest that students may have a misconception that moist air has a higher density than dry air.

Other possible misconceptions may come from items 3, 4, 5, and 7. Although they do not have the support that items 1 and 8 had, they still show significant signs of students having misconceptions. Question 3 is as follows:

3. Which statement is true?
   
   A. Water can evaporate at any temperature.
   
   B. Water can only evaporate if it is boiled.
   
   C. Water can only evaporate at 100°C
   
   D. Ice has to melt before it can evaporate.

The correct answer to item 3 is A (water can evaporate at any temperature). On the pre-test significantly more students chose response D (ice has to melt before it can evaporate). This held true for both the results for all of the students and for the treatment group alone. This suggests that students may hold the misconception that ice cannot go directly to the vapor phase and that water cannot evaporate at every temperature.
Item 4 had similar results as item 3. Question 4 is as follows:

4. Frost forms when:

   A. Water vapor changes directly to a solid at temperatures below 0°C.

   B. Dew forms at temperatures above 0°C then freezes when the temperature goes below 0°C

   C. Snow falls to the ground at temperatures below 0°C and has stuck to objects at or near the earth’s surface.

   D. Rain falls to the ground at temperatures above 0°C and freezes when the temperatures drop below 0°C.

The correct answer is A (water vapor changes directly to a solid at temperatures below 0°C). On the pre-test significantly more students chose B over any of the other choices. Interestingly the treatment group’s post-test shows that there was not a significant difference between the number of students who chose B and who answered it correctly with A, but on the post-post-test significantly more students chose B over any other choice including the correct answer. These results suggest that students have a misconception that water vapor cannot change directly to a solid. It also suggests that even though some students overcame this misconception, they reverted back to it after time.
The results from item 5 also suggest that students have another misconception. Question 5 is as follows:

5. What shape does a raindrop have?
   A. Like a pear
   B. Like a grapefruit
   C. Like a hamburger bun
   D. Like a carrot

The correct answer to item 5 is C (like a hamburger bun). On the pre-test and post-test results that included both groups, significantly more students chose A over any other choices. This also held true for the pre-test results for just the treatment group. This result suggests that students have the misconception that raindrops look more like a pear than having a flat side like a hamburger bun. On the post-test and post-post-test for the treatment group more students still chose A over the rest of the choices, but it was only significant over B and D which means some students were able to overcome the misconception.

One last possible misconception comes from item 7. Question 7 is as follows:

7. What happens to a water molecule when it evaporates?
   A. It contains more energy than it did when it was liquid water.
   B. It separates into its elemental parts of oxygen and hydrogen.
   C. It slows down and becomes suspended in the air.
   D. It clings to molecules in the air, which keep it in the air as water vapor.
The correct answer to item 7 is A (it contains more energy than it did when it was liquid water). On the post-test for all the students combined and on the post-test for the treatment group, significantly more students chose D (it clings to molecules in the air, which keep it in the air as water vapor). The same was found to be true on the pre-test, but the confidence rating did not reach the 2.5 threshold. This suggests that students do not realize that water gains more energy in order to evaporate, and think that the water vapor has to hold onto something in the air to stay in the air. On the post-post-test for the treatment group students chose choice D significantly more than B and C, but some of them overcame the misconception and answered it correctly which is why there was not a significant difference between the correct answer A and the misconception D.

In summary, the data collection tool may have been able to identify a few misconceptions that students have about water in the atmosphere and the processes in the water cycle. Many of these possible misconceptions align with Ben-zvi-Assarf & Orion’s (2005) study that found students “most of the students had difficulties to perceive the transformation of matter (water) in the earth reservoirs, and to synthesize components into a coherent system” (p.373). The follow is a list of the identified possible misconceptions found in this study:

1. Clouds are made of water vapor.
2. Moist air is more dense than dry air.
3. Ice cannot go directly to the vapor phase.
4. Water cannot evaporate at every temperature.
5. Water vapor cannot change directly to a solid.
6. Raindrops look more like a pear than having a flat side like a hamburger bun.
7. Students do not realize that water gains energy in order to evaporate

8. Students think that the water vapor has to hold onto something in the air to stay in the air.

The specific misconceptions that are identified here may not really be the misconceptions as they are identified. Remember that each of the nine items on the tool encompasses one or more of three general underlying scientific concepts:

1. Properties of the states of matter
2. Changing between states of matter
3. Energy’s involvement in the states of matter and changing between the different states.

Therefore, students may have misconceptions about these underlying scientific principles that inhibit their ability to construct a correct understanding about water and water processes in the water cycle. Ben-zvi-Assarf & Orion (2005)

This aligns with Dole and Sinatra’s (1998) view of conceptual change. Students may have a strong grip on the conceptions because of what they already know, or the conception has a good coherence with the students understanding, or even that the students’ commitments to their beliefs or prior experiences about the topics were too deeply rooted. Ben-zvi-Assarf & Orion (2005) found that students enter and leave the secondary education setting with the same misconceptions. This list may show the same phenomenon. Since students normally do not receive education on the water cycle post eighth grade in the sample population’s school, they these student may have entered and
are leaving this school with the same incorrect ideas about certain specific areas within the water cycle.

Research question 4. What is the origin of a misconception identified by this study?

The data collection tool used an open-ended response for students to express where they believed they might have gained the knowledge to answer each item on the tool. Locating the origin of the misconception can be useful for teachers to try and tailor lessons to address the misconceptions helping student overcome them (Bar, 1989). For all the items except item 5 students indicated that they had learned the material in school in previous years. So the results, therefore, would suggest that most misconceptions are actually formed in school. However, most of the responses were too vague to pinpoint where or how in school they may have come up with the incorrect ideas. But for item 5, which dealt with the misconception that raindrops look more like a pear than having a flat side like a hamburger bun, there were a variety of responses. Although a large number of students suggested school as the main location for acquiring the knowledge, most students cited books, TV, and other media for teaching them the shape of a raindrop. Also, a large number of students said they were able construct this knowledge on their own through “common sense” or their “own experience.”

Although the responses for item 5 are interesting, and most other responses for the other identified misconceptions point to school as the misconception producer, these
results do not specifically pinpoint what is creating the misconception. The response categories are too vague to give exact results.

**Recommendations**

The findings in this study coupled with its limitations led to the following recommendations:

*Regarding the Student Sample.*

The sample in this study came from eighth grade in a middle-class suburban junior-senior high school. Therefore, it makes it hard to generalize these results to other school settings as well as other age groups. Additional samples from urban, rural and other suburban schools would add to the ability to generalize the results of the study. Likewise, if high school age students would be added to the study it would be able to generalize vertically as well as horizontally.

One uncontrollable aspect of the investigation was the student sample used. Since students are assigned by the school administration based on their ability, it takes out the randomness in the selection of the students. To solidify this study, it is recommended that the study be conducted again in a sample where a more random approach can be taken in selecting the study’s student population.

*Regarding the Methodology*

The researcher in this study was also the instructor for the four treatment groups. One teacher, the researcher, affected the outcome of the study. Although a daily journal was kept and was discussed weekly with a third party, the use of other teachers in the study would have helped to eliminate bias in the study toward discovery learning. Therefore it is recommended that any future studies use multiple teachers and that those
teachers are not the researcher. This will help to eliminate bias toward the outcome of the study.

A second concern about the methodology is the use of the comparison group. Because there is no real comparison group covering the same information in a more traditional manner, the results here may not be as significant as they appear. The comparison group was subjected to an entirely different curriculum during the study. Therefore any gains by the treatment group may have resulted simply because the treatment group was exposed to the content and the comparison group was not. It is recommended then that if the study is completed again that a true control group is used in order to see if significant gains are made by the discovery learning group and a traditional group covering the same material.

**Regarding Misconceptions**

Although the study suggests there are several misconceptions found in the given sample, there is still a chance they are just non-conceptions where students just do not know the answers. In order to solidify the results of the specific misconceptions found in this study, a larger sample would better discriminate or differentiate between non-conception and misconceptions. A second recommendation to help identify misconceptions would be the use of interviews of students to discuss their answers. This would allow researchers to separate non-conceptions from misconceptions based on the oral responses that students gave.

The study did not clearly discover where the possible misconceptions originated. It is recommended that future researchers refine the method of collecting the data on origins of the students’ understanding. This research found that the created categories
were too broad to pinpoint the misconceptions. It might be helpful to expand the categories, and even change the open-ended response to a checklist that incorporates the new categories.

Another study that should be run is a test of different pedagogical methods in order to attempt to overcome the misconceptions found in this study. This study shows there was little gain in students’ scores even though the gain was significant. One of the possibilities is that students’ misconceptions may be interfering with learning the content on the data collection tool. A second possibility is students may have misconceptions about the underlying science principles imbedded in the content of the data collection tool. Therefore, a study could be conducted to identify if students have misconceptions about they underlying principles.

Regarding Science Teaching

From a teacher’s perspective, identifying misconception prior to starting a unit or a lesson can help an educator tailor his lesson to help students confront them making a more meaningful lesson. Whether teachers focus on common misconceptions found through others research or they use a tool like the one used in this study, it will give them the upper hand at helping students gain greater understanding about science concepts. The research suggested that if students are able to have sound foundations later learning may be more fruitful.

A second recommendation for science educators is how they analyze the assessments that they use. It is worth noting that using a more in-depth item analysis can help teachers to identify concepts that may be giving students problems. It could be to identify misconceptions or simply to identify a confusing question or misunderstood
choice on a test. Identifying the problems allows the teacher to revisit the concept to clarify what the students did not know or be able to guide the students to a better understanding of the concept.

**Researcher’s Final Thoughts and Recommendations.**

As a teacher I have always strived to make a positive impact on my students both academically and as citizens. Thus birthed the idea of the research laid out in this study. I believe it is my professional responsibility to try and implement any pedagogical philosophies that may elevate my students academically. I also believe it is my duty as an American citizen to give my students what they need to be effective in a highly competitive world. Although not all of the expectations in this study were reached, I believe there is enough evidence that discovery learning may work with my specific population of students. From the findings, I also believe it is imperative to identify the misconceptions that students have because they may be the root to the small gains in this study. But allowing students to challenge and hopefully overcome the misconceptions they have, they may be able to gain greater knowledge in my class and have fewer problems in classes they have in the future. This will give me another tool to use in order to help me accomplish my professional goals and responsibilities.

I would encourage other researchers to test the gaps in this research and expand on them in order to fill the gaps exposed by this study. The more scientific research that goes into students’ understanding of processes and misconceptions will inspire other pedagogical practices that will help all teachers in their quest to help children learn.
BIBLIOGRAPHY


Parker, E. A. (2010). The relationship between nature of science understandings and science self-efficacy beliefs of sixth grade students. Atlanta Georgia: Department of Middle-Secondary Education and Instructional Technology at Digital Archive @ GSU.


APPENDIX A

PERMISSION SLIP TO USE STUDENT DATA AND STUDENT ASSENT

FORM

Permission to Take Part in a Human Research Study.

**Title of research study:** The impact of discovery learning on achievement, overcoming misconceptions about the water cycle, and students’ self-efficacy in science.

**Investigator:** John D. Yoder Jr.

I invite you to take part in a research study because you are enrolled in the student subject pool. This study involves your children, so “you” or “your” will refer to your child.

**What you should know about a research study**
- You volunteer to be in a research study.
- Whether you take part is up to you.
- You can choose not to take part in the research study.
- You can agree to take part now and later change your mind.
- Whatever you decide, it will not be held against you.
- Feel free to ask all the questions you want before and after you decide.

**Who can I talk to?**
If you have questions, concerns, or complaints, or think the research has hurt you, contact the research team at 630 Evans Ave. Wyomissing, PA 19610 attention John Yoder, jyoder@wyoarea.org, 610-374-0739 ext. 2208.

This research has been reviewed and approved by an Institutional Review Board at Temple University. You may talk to them at (215) 707-3390 or e-mail them at: irb@temple.edu for any of the following:
- Your questions, concerns, or complaints are not being answered by the research team.
- You cannot reach the research team.
- You want to talk to someone besides the research team.
- You have questions about your rights as a research subject.
- You want to get information or provide input about this research.

**Why am I doing this research?**
During this semester your son/daughter will fill out a meteorology and a science self-efficacy survey. The responses from the survey are going to be used to measure the effectiveness of inquiry and discovery learning on student achievement. Also the results from their unit test in meteorology will be used in the measurement. The collective results of all the student surveys will be used in research for my doctoral dissertation. The
entire project will keep all participants anonymous. No individual’s name will be used in the dissertation or in subsequent reports written for the project. The research is solely intended to benefit science teachers across the nation by giving them a tool to help design their curriculum.

**How long will the research last?**
I expect that you will be in this research study from 3 weeks to 1 month which is the approximate time it will take you to complete a unit in meteorology in class.

**How many people will be studied?**
I expect about 150 students here will be in this research study which is the entire 8th grade at Wyomissing School District.

**What happens if I say yes, I want to be in this research?**
- You will be asked to fill out a pre-unit survey.
- You will be asked to fill out a post-unit survey.
- Your data will be analyzed comparing your pre-unit responses to your post-unit responses.
- Your responses will be compared to your peers’ responses.

**What are my responsibilities if I take part in this research?**
If you take part in this research, you will be responsible for completing both the pre-unit and post-unit surveys and you agree to allow your responses to be anonymously used in the study.

**What happens if I say no, I do not want to be in this research?**
You may decide not to take part in the research and it will not be held against you. All of your answers to the surveys will be omitted from the study.

**What happens if I say yes, but I change my mind later?**
You can agree to take part in the research now and you can stop at any time, it will not be held against you.

**What happens to the information I collect?**
Efforts will be made to limit your personal information to people who have a need to review this information. We cannot promise complete secrecy. For example, though the study team has put in safeguards to protect your information, there is always a potential risk of loss of confidentiality. Organizations that may inspect and copy your information include the IRB, Temple University and its affiliates, and other representatives of these organizations, and the Office of Human Research Protections. We may publish the results of this research. However, we will keep your name and other identifying information confidential.

**Can I be removed from the research without my permission?**
The person in charge of the research study or the sponsor can remove you from the research study without your approval. Possible reasons for removal include but are not limited to extended absentness from school during the study, you not taking the surveys seriously, etc. The sponsor can also end the research study early.

Your signature documents your permission for the named child to take part in this research.

DO NOT SIGN THIS FORM AFTER THIS DATE

_________________________
Printed name of child

_________________________
Signature of parent or guardian

_________________________
Printed name of parent or guardian

☐ Parent
☐ Guardian

_________________________
Date
Discovery Learning, Misconceptions, and Science Self-efficacy

My name is Mr John Yoder. I am a student at Temple University.

I am asking you to take part in a research study because I am trying to learn more about discovery learning. I want to learn about misconceptions kids your age have about the water cycle and how confident you are about science.

If you agree, you will be asked to complete a survey. You will be asked a few questions about the water cycle. You will also be asked questions about how confident you are about science. Answering these questions will take about 20 minutes. After a unit in meteorology you will be asked to complete the surveys once again.

You do not have to be in this study. No one will be mad at you if you decide not to do this study. Even if you start, you can stop later if you want. You may ask questions about the study.

If you decide to be in the study I will not tell anyone else what you say or do in the study. Even if your parents or teachers ask, I will not tell them about what you say or do in the study.

Signing here means that you have read this form or have had it read to you and that you are willing to be in this study.

Signature of subject______________________________________________________

Subject's printed name___________________________________________________

Signature of investigator__________________________________________________

Date___________________________
APPENDIX B

SELF-EFFICACY SURVEYS

Name:________________

Directions:
1. This survey contains a number of statements about science. You will be asked what you think about these statements. There are no “right” or “wrong” answers. Your opinion is what is wanted.
2. For each statement, draw a circle around the specific numeric value corresponding to how you feel about each statement. Please circle only ONE value per statement.

5 = Strongly Agree (SA)
4 = Agree (A)
3 = Uncertain (U)
2 = Disagree (D)
1 = Strongly Disagree (SD)

<table>
<thead>
<tr>
<th></th>
<th>SA</th>
<th>A</th>
<th>U</th>
<th>D</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I can always figure out the main idea in science class.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2. When I do not understand something in science, I know where to find help.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3. It is not hard for me to come up with a question to research, when I do a science project.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>4. I know how to use the scientific method to solve problems.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>5. When I do my work in science class, I am able to find the important ideas.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>6. I am able to apply what I learn in science to things that I experience or read about.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>7. I can design an experiment to test my ideas.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>8. In general, I am confident that I can achieve at a high level in science.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
APPENDIX C

MISCONCEPTION IDENTIFICATION TOOL

Name: ________________________

**DIRECTIONS:** Choose and circle the best answer for each question or statement. After answering each question, rate how confident you are in your answer by circling the statement on the Confidence Rating Scale that best describes how confident you are in your answer from 1 "you definitely do not know" to 4 "you definitely know". Also indicate where you thought you may have learned the information presented in the question in the space provided.

1. When you look at a cloud you are looking at:
   A. Water Vapor
   B. Smoke
   C. Steam
   D. Liquid water and/or ice

   *Where did I learn this?*

2. Warm air allows more water vapor to exist in the air because:
   A. There is more space between air molecules for the water molecules.
   B. There is more energy available for water molecules to be in the vapor state.
   C. Warm air is more dense.
   D. Warm air exerts more pressure on the water molecules.

   *Where did I learn this?*

3. Which statement is true?
   A. Water can evaporate at any temperature.
   B. Water can only evaporate if it is boiled.
   C. Water can only evaporate at 100°C.
   D. Ice has to melt before it can evaporate.

   *Where did I learn this?*

4. Frost forms when:
   A. Water vapor changes directly into a solid at temperatures below 0° C.
   B. Dew forms at temperatures above 0° C and then freezes when the temperature drops below 0° C.
   C. Snow falls to the ground at temperatures below 0° C and has stuck to object at or near the earth’s surface.
   D. Rain falls to the ground at temperatures above 0° C and then freezes when the temperature drops below 0° C.

   *Where did I learn this?*
5. What shape does a raindrop have?
   A. Like a pear
   B. Like a grapefruit
   C. Like a hamburger bun
   D. Like a carrot
   
   Where did I learn this?

6. For clouds to form:
   A. Air needs to rise.
   B. Air needs to sink.
   C. Air needs to move horizontally.
   
   Where did I learn this?

7. What happens to a water molecule when it evaporates?
   A. It contains more energy than it did when it was liquid water.
   B. It separates into its elemental parts of oxygen and hydrogen
   C. It slows down and becomes suspended in the air.
   D. It clings onto molecules in the air, which keep it in the air as water vapor.
   
   Where did I learn this?

8. Which of the following would be more dense at sea level and 15° C?
   A. Moist air
   B. Dry air
   
   Where did I learn this?

9. What happens when the relative humidity reaches 100%?
   A. It rains
   B. Condensation occurs
   C. Air starts to rise.
   D. Air starts to sink.
   
   Where did I learn this?
### APPENDIX D

**STUDENT LEARNING AND UNDERSTANDING GUIDE**

<table>
<thead>
<tr>
<th>Topic: Meteorology</th>
<th>Unit Essential Question(s):</th>
<th>Lesson Essential Questions:</th>
<th>Vocabulary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1. How does the sun, earth, and air interact to create the weather on the earth?</td>
<td>1. How do tornadoes and hurricanes differ?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. Differentiate between tornadoes and hurricanes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Explain how water moves through the water cycle.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. Explain how the Earth's atmosphere is warmed.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. Heating the Earth's atmosphere</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. How does water move through the water cycle.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. Differentiate between fronts and cold, warm fronts</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. How do tornadoes and hurricanes differ?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. How do tornadoes and hurricanes differ?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. How do tornadoes and hurricanes differ?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. How do tornadoes and hurricanes differ?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Concept:**
- Sever Weather
- Skills:
  - Differentiate between tornadoes and hurricanes
  - Explain how water moves through the water cycle
  - Heating the Earth's atmosphere

**Vocabulary:**
- Air Mass
- Cumulus cloud
- Cirrus cloud
- Condensation
- Condensation Nuclei
- Deposition
- Evaporation
- Precipitation
- Sublimation
- Infrared Radiation

**Notes:**
- This table outlines key concepts and questions related to meteorology, focusing on student learning and understanding.
APPENDIX E

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION’S

DIAGRAM OF THE WATER CYCLE
### APPENDIX G

**RELATIVE HUMIDITY AND DEW POINT CHARTS**

Below is a chart showing the relationship between dry-bulb temperature (°C) and relative humidity (%). The chart is designed to help determine the difference in temperatures between wet and dry bulb conditions, which is essential for understanding dew point and relative humidity in environmental studies and HVAC systems.

<table>
<thead>
<tr>
<th>Dry-Bulb Temp (°C)</th>
<th>Difference Between Wet and Dry Bulb Temp (°C)</th>
<th>Relative Humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10</td>
<td></td>
<td>67</td>
</tr>
<tr>
<td>-9</td>
<td></td>
<td>69</td>
</tr>
<tr>
<td>-8</td>
<td></td>
<td>71</td>
</tr>
<tr>
<td>-7</td>
<td></td>
<td>73</td>
</tr>
<tr>
<td>-6</td>
<td></td>
<td>74</td>
</tr>
<tr>
<td>-5</td>
<td></td>
<td>75</td>
</tr>
<tr>
<td>-4</td>
<td></td>
<td>77</td>
</tr>
<tr>
<td>-3</td>
<td></td>
<td>78</td>
</tr>
<tr>
<td>-2</td>
<td></td>
<td>79</td>
</tr>
<tr>
<td>-1</td>
<td></td>
<td>81</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>83</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>84</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>86</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>88</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>90</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>92</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>94</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>96</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>98</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>17</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>19</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>21</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>22</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>23</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>24</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>26</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>27</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>28</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>29</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>30</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>31</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>32</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>33</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>34</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>35</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Dry-Bulb Temp (°C)</td>
<td>Difference Between Wet and Dry Bulb Temp (°C)</td>
<td></td>
</tr>
<tr>
<td>-------------------</td>
<td>---------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>-20</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>-15</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>-10</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>-9</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>-8</td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>-7</td>
<td>-11</td>
<td></td>
</tr>
<tr>
<td>-6</td>
<td>-13</td>
<td></td>
</tr>
<tr>
<td>-5</td>
<td>-15</td>
<td></td>
</tr>
<tr>
<td>-4</td>
<td>-17</td>
<td></td>
</tr>
<tr>
<td>-3</td>
<td>-19</td>
<td></td>
</tr>
<tr>
<td>-2</td>
<td>-21</td>
<td></td>
</tr>
<tr>
<td>-1</td>
<td>-23</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>-25</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>-27</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-29</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>-31</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>-33</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>-35</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>-37</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>-39</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>-41</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>-43</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>-45</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>-47</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>-49</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>-51</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>-53</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>-55</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>-57</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>-59</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>-61</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>-63</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>-65</td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- Dry-Bulb Temp (°C): Temperature measured with a dry bulb thermometer.
- Difference Between Wet and Dry Bulb Temp (°C): The difference between the wet bulb and dry bulb temperatures.
APPENDIX H

PROJECT DESCRIPTIONS FOR THE WATER CYCLE: PATH 1 INDIVIDUAL STORY; PATH 2 GROUP PLAY; PATH 3 INDIVIDUAL VIDEO/POD CAST

The Hydrologic Cycle

Your name is Molly, and you are a water molecule. You have just been hired by a big time publishing company to write your autobiography. They want to know every detail of your life as you went through the hydrologic cycle. They have given you a list of terms and concepts that they want you to cover as you tell your story. The topics to be covered consist of:

- Relative humidity
- Dew point
- Evaporation
- Condensation
- Condensation nuclei
- Temperature
- Precipitation
- Clouds (formation)

The publishing company informs you that you may also include any other aspect of your life that you feel is important, which may not be mentioned in the list above.

When you finish your story you will need to present it to the publishing company. Also, they decided to put a deadline on your project so working fast and efficiently is a must. Attached to this letter is a pay scale for your work and a few simple ground rules. Thank you and good luck!

Sincerely,

Yoda D. Master, ESQ
Pay For Work Done

_____ Each topic is worth 5 points each (50 points)
    _____ Relative humidity
    _____ Dew point
    _____ Evaporation
    _____ Deposition
    _____ Sublimation
    _____ Condensation
    _____ Condensation nuclei
    _____ Temperature
    _____ Precipitation
    _____ Clouds (formation)

_____ Bibliography 10 points (proper citations in MLA format/at least 3 sources)

_____ Proper English 10 points (spelling, grammar, etc.)

_____ Interrelation of terms 10 points

_____ Over all quality 10 points (organization, uniqueness, etc.)

_____ Total

90
APPENDIX I

PROJECT DESCRIPTION OF THE WATER CYCLE: PATH 4

The Hydrologic Cycle

You are an engineer and you have just been hired by a big time scientific supply company to construct a model of the water cycle that will be distributed to universities across the country. They want to know every detail of what happens to a water molecule as it moves through the hydrologic cycle. They have given you a list of terms and concepts that they want you to incorporate as you design your model. The topics to be covered consist of:

- Relative humidity
- Dew point
- Evaporation
- Condensation
- Condensation nuclei
- Temperature
- Precipitation
- Clouds (formation)

The supply company informs you that you may also include any other aspect of the water cycle that you feel is important, which may not be mentioned in the list above. When you finish your model you will need to present it to the supply company. Also, they decided to put a deadline on your project so working fast and efficiently is a must. Attached to this letter is a pay scale for your work and a few simple ground rules. Thank you and good luck!

Sincerely,

Yoda D. Master, ESQ
Pay For Work Done

_____Each topic is worth 5 points each (50 points)
    _____Relative humidity
    _____Dew point
    _____Evaporation
    _____Deposition
    _____Sublimation
    _____Condensation
    _____Condensation nuclei
    _____Temperature
    _____Precipitation
    _____Clouds (formation)

_____Bibliography 10 points (proper citations in MLA format/ at least 3 sources)
_____Explanation to class shows understanding of processes 10 points.
_____Explains the interrelationship of terms 10 points
_____Over all quality 10 points (organization, uniqueness, etc.)

_____ Total
  90
APPENDIX J

DAILY JOURNAL DURING THE STUDY

Monday, August 27, 2012

• **Per 3 Academic ESS:** First day of school. Short classes. Handed out books and went over expectations of the book.

• **Per 4 Academic ESS:** First day of school. Short classes. Handed out books and went over expectations of the book.

• **Per 6 Advanced ESS:** First day of school. Short classes. Handed out books and went over expectations of the book.

• **Per 8 Advanced ESS:** First day of school. Short classes. Handed out books and went over expectations of the book.

Tuesday, August 28, 2012

• **Per 3 Academic ESS:** Handed out syllabus. Went over the rules and expectations.

• **Per 4 Academic ESS:** Handed out syllabus. Went over the rules and expectations.

• **Per 6 Advanced ESS:** Handed out syllabus. Went over the rules and expectations.

• **Per 8 Advanced ESS:** Handed out syllabus. Went over the rules and expectations.

Wednesday, August 29, 2012

• **Per 3 Academic ESS:** Went over how to do Current Events in class (from Syllabus). Handed out student assent forms to be filled out. Handed out Parental
permission forms to be signed (due date Fri. 9/7). Had students fill out the Self-efficacy survey, and the data collection tool test.

- **Per 4 Academic ESS:** Went over how to do Current Events in class (from Syllabus). Handed out student assent forms to be filled out. Handed out Parental permission forms to be signed (due date Fri. 9/7). Had students fill out the Self-efficacy survey, and the data collection tool test.

- **Per 6 Advanced ESS:** Went over how to do Current Events in class (from Syllabus). Handed out student assent forms to be filled out. Handed out Parental permission forms to be signed (due date Fri. 9/7). Had students fill out the Self-efficacy survey, and the data collection tool test.

- **Per 8 Advanced ESS:** Went over how to do Current Events in class (from Syllabus). Handed out student assent forms to be filled out. Handed out Parental permission forms to be signed (due date Fri. 9/7). Had students fill out the Self-efficacy survey, and the data collection tool test.

Thursday, August 30, 2012

- **Per 3 Academic ESS:** Introduced the idea of a concept map to the class. Used simplistic terms to create one with the class (cat, dog, bird). Gave the class the list of vocab from the Water Cycle concept on the SLUG (condensation, condensation nuclei, deposition, dew point, evaporation, precipitation, relative humidity, sublimation). Told the class to work individually to put the terms into a concept map. Students struggled with the meaning of the terms, really struggled with how to organize them into a concept map. The whole day was an epic fail! Threw out the concept maps. They were not what I wanted.
• **Per 4 Academic ESS:** Introduced the idea of a concept map to the class. Used simplistic terms to create one with the class (cat, dog, bird). Gave the class the list of vocab from the Water Cycle concept on the SLUG (condensation, condensation nuclei, deposition, dew point, evaporation, precipitation, relative humidity, sublimation). Told the class to work individually to put the terms into a concept map. Students struggled with the meaning of the terms, really struggled with how to organize them into a concept map. The whole day was an epic fail! Threw out the concept maps. They were not what I wanted.

• **Per 6 Advanced ESS:** Introduced the idea of a concept map to the class. Used simplistic terms to create one with the class (cat, dog, bird). Gave the class the list of vocab from the Water Cycle concept on the SLUG (condensation, condensation nuclei, deposition, dew point, evaporation, precipitation, relative humidity, sublimation). Told the class to work individually to put the terms into a concept map. Students struggled with the meaning of the terms, really struggled with how to organize them into a concept map. The whole day was not a complete epic fail, but the maps left something to be desired. Threw out the concept maps. They were not what I wanted.

• **Per 8 Advanced ESS:** Introduced the idea of a concept map to the class. Used simplistic terms to create one with the class (cat, dog, bird). Gave the class the list of vocab from the Water Cycle concept on the SLUG (condensation, condensation nuclei, deposition, dew point, evaporation, precipitation, relative humidity, sublimation). Told the class to work individually to put the terms into a concept map. Students struggled with the meaning of the terms, really struggled
with how to organize them into a concept map. The whole day was not a complete epic fail, but the maps left something to be desired. Threw out the concept maps. They were not what I wanted.

- **After school:** Sat down with dept. chair (third party person) and discussed what I did this week. Short discussion. Decided that I was going to drop the first concept map from study.

Friday, August 31, 2012

- No school

Monday, September 3, 2012

- No school

Tuesday, September 4, 2012

- **Per 3 Academic ESS:** Reviewed the scientific process from last year. Used the tube of wonder to illustrate the process.

- **Per 4 Academic ESS:** Reviewed the scientific process from last year. Used the tube of wonder to illustrate the process.

- **Per 6 Advanced ESS:** Reviewed the scientific process from last year. Used the tube of wonder to illustrate the process.

- **Per 8 Advanced ESS:** Reviewed the scientific process from last year. Used the tube of wonder to illustrate the process.

Wednesday, September 5, 2012

- **Per 3 Academic ESS:** Gave the class the SLUG. Explained the set up of it. Gave the class definition sheets. Explained the set up. Explained the “what is it like box”. Told students that not all words were in the textbook and they may
have to use other resources to find them. Showed them where other science books were in the room, and told them they could use the computers in the room. They worked in pairs to define and come up with the “what is it like” for each word. Did not assign what they had not finished for homework.

- **Per 4 Academic ESS**: Gave the class the SLUG. Explained the set up of it. Gave the class definition sheets. Explained the set up. Explained the “what is it like box”. Told students that not all words were in the textbook and they may have to use other resources to find them. Showed them where other science books were in the room, and told them they could use the computers in the room. They worked in pairs to define and come up with the “what is it like” for each word. Did not assign what they had not finished for homework.

- **Per 6 Advanced ESS**: Gave the class the SLUG. Explained the set up of it. Gave the class definition sheets. Explained the set up. Explained the “what is it like box”. Told students that not all words were in the textbook and they may have to use other resources to find them. Showed them where other science books were in the room, and told them they could use the computers in the room. They worked in pairs to define and come up with the “what is it like” for each word. Did not assign what they had not finished for homework.

- **Per 8 Advanced ESS**: Gave the class the SLUG. Explained the set up of it. Gave the class definition sheets. Explained the set up. Explained the “what is it like box”. Told students that not all words were in the textbook and they may have to use other resources to find them. Showed them where other science books were in the room, and told them they could use the computers in the room.
They worked in pairs to define and come up with the “what is it like” for each word. Did not assign what they had not finished for homework.

Thursday, September 6, 2012

- **Per 3 Academic ESS**: Had students continue to work on the vocab. What they did not finish today became homework.

- **Per 4 Academic ESS**: Had students continue to work on the vocab. What they did not finish today became homework.

- **Per 6 Advanced ESS**: Had students continue to work on the vocab. What they did not finish today became homework. Most of the students finished in class.

- **Per 8 Advanced ESS**: Had students continue to work on the vocab. What they did not finish today became homework. Most of the students finished in class.

Friday, September 7, 2012

- **Per 3 Academic ESS**: Started the 1st concept from the SLUG “Heating the Atmosphere. Had students create a diagram that showed what happens to incoming radiation from the sun. Incorporated Vocab (looked at vocab sheets to check for understanding) into the diagram. Did not finish.

- **Per 4 Academic ESS**: Started the 1st concept from the SLUG “Heating the Atmosphere. Had students create a diagram that showed what happens to incoming radiation from the sun. Incorporated Vocab (looked at vocab sheets to check for understanding) into the diagram. Did not finish.
• **Per 6 Advanced ESS:** Started the 1\textsuperscript{st} concept from the SLUG “Heating the Atmosphere. Had students create a diagram that showed what happens to incoming radiation from the sun. Incorporated Vocab (looked at vocab sheets to check for understanding) into the diagram. Did not finish.

• **Per 8 Advanced ESS:** Started the 1\textsuperscript{st} concept from the SLUG “Heating the Atmosphere. Had students create a diagram that showed what happens to incoming radiation from the sun. Incorporated Vocab (looked at vocab sheets to check for understanding) into the diagram. Did not finish.

• **After school:** Sat down with dept. chair and discussed what I did this week. She liked the idea of the vocab. Decided all of the classes were still being taught the same.

Monday, September 10, 2012

• **Per 3 Academic ESS:** Reviewed from Friday. Finished incoming solar radiation diagram. Went over Green house effect with notes. Helped students create a diagram of a sea breeze. Assigned a Land breeze diagram for homework.

• **Per 4 Academic ESS:** Reviewed from Friday. Finished incoming solar radiation diagram. Went over Green house effect with notes. Helped students create a diagram of a sea breeze. Assigned a Land breeze diagram for homework.

• **Per 6 Advanced ESS:** Reviewed from Friday. Finished incoming solar radiation diagram. Went over Green house effect with notes. Helped students create a diagram of a sea breeze. Assigned a Land breeze diagram for homework.

Tuesday, September 11, 2012
• **Per 3 Academic ESS:** Went over land breeze from homework. Gave notes on global wind patterns and their relation to weather patterns.

• **Per 4 Academic ESS:** Went over land breeze from homework. Gave notes on global wind patterns and their relation to weather patterns.

• **Per 6 Advanced ESS:** Went over land breeze from homework. Gave notes on global wind patterns and their relation to weather patterns.

• **Per 8 Advanced ESS:** Went over land breeze from homework. Gave notes on global wind patterns and their relation to weather patterns.

Wednesday, September 12, 2012

• **Per 3 Academic ESS:** Did the Sling psychrometer demonstration. Left the students with the question “Why does the wet bulb show a lower temperature?” Students were put in small groups to try and figure out the answer to the question. After a short time used a jig-saw activity to allow students to interact with other groups. Finished up the activity with a group discussion led by the students. Told the students that for the second column of the SLUG “The Water Cycle” that I would not be giving any notes for it. They were going to have to figure out how the vocab fit into it by themselves. Handed out the Molly the molecule papers. Went over the project with them and explained their options. Told them they would have 3 days in class and the weekend to work on it that it was due Tuesday 9/18. Their homework was to decide what project they wanted to do.

• **Per 4 Academic ESS:** Did the Sling psychrometer demonstration. Left the students with the question “Why does the wet bulb show a lower temperature?” Students were put in small groups to try and figure out the answer to the question.
After a short time used a jig-saw activity to allow students to interact with other groups. Finished up the activity with a group discussion led by the students. Told the students that for the second column of the SLUG “The Water Cycle” that I would not be giving any notes for it. They were going to have to figure out how the vocab fit into it by themselves. Handed out the Molly the molecule papers. Went over the project with them and explained their options. Told them they would have 3 days in class and the weekend to work on it that it was due Tuesday 9/18. Their homework was to decide what project they wanted to do.

- **Per 6 Advanced ESS:** Did the Sling psychrometer demonstration. Left the students with the question “Why does the wet bulb show a lower temperature?” Students were put in small groups to try and figure out the answer to the question. After a short time used a jig-saw activity to allow students to interact with other groups. Finished up the activity with a group discussion led by the students. Told the students that for the second column of the SLUG “The Water Cycle” that I would not be giving any notes for it. They were going to have to figure out how the vocab fit into it by themselves. Handed out the Molly the molecule papers. Went over the project with them and explained their options. Told them they would have 3 days in class and the weekend to work on it that it was due Tuesday 9/18. Their homework was to decide what project they wanted to do.

- **Per 8 Advanced ESS:** Did the Sling psychrometer demonstration. Left the students with the question “Why does the wet bulb show a lower temperature?” Students were put in small groups to try and figure out the answer to the question. After a short time used a jig-saw activity to allow students to interact with other
groups. Finished up the activity with a group discussion led by the students. Told the students that for the second column of the SLUG “The Water Cycle” that I would not be giving any notes for it. They were going to have to figure out how the vocab fit into it by themselves. Handed out the Molly the molecule papers. Went over the project with them and explained their options. Told them they would have 3 days in class and the weekend to work on it that it was due Tuesday 9/18. Their homework was to decide what project they wanted to do.

Thursday, September 13, 2012

- **Per 3 Academic ESS:** Worked on Molly the whole period. Help individual groups/students that needed it. Some students in this class needed help getting started. Between my classroom aid and me we were able to help all the students get an idea of how to get started.

- **Per 4 Academic ESS:** Worked on Molly the whole period. Help individual groups/students that needed it. Some students in this class needed help getting started. Some groups needed to sit down and just look at the vocab, and what the water cycle was.

- **Per 6 Advanced ESS:** Worked on Molly the whole period. Help individual groups/students that needed it. By the end of the period all groups were in full work mode.

- **Per 8 Advanced ESS:** Worked on Molly the whole period. Help individual groups/students that needed it. By the end of the period all groups were in full work mode.

Friday, September 14, 2012
• **Per 3 Academic ESS:** Worked on Molly the whole period. All groups worked very well.

• **Per 4 Academic ESS:** Worked on Molly the whole period. All groups worked very well.

• **Per 6 Advanced ESS:** Worked on Molly the whole period. All but one group of boys worked very well. Had to spend most of my time focusing the off-task group.

• **Per 8 Advanced ESS:** Worked on Molly the whole period. All groups worked well.

• **After school:** Sat down with dept. chair and discussed what I did this week. Talked about the sling psychrometer demo. Decided I did not lead them in any direction based on what I did. Decided I was appropriately leading students doing Molly, and not “giving” them answers.

Monday, September 17, 2012

• **Per 3 Academic ESS:** Worked on Molly the whole period. All groups worked very well.

• **Per 4 Academic ESS:** Worked on Molly the whole period. All groups worked very well.

• **Per 6 Advanced ESS:** Worked on Molly the whole period. All groups worked very well.

• **Per 8 Advanced ESS:** Worked on Molly the whole period. All groups worked well.
Tuesday, September 18, 2012

- **Per 3 Academic ESS**: Groups handed in their projects. The groups that needed to present started to present. Did not finish presentations.

- **Per 4 Academic ESS**: Groups handed in their projects. The groups that needed to present started to present. Did not finish presentations.

- **Per 6 Advanced ESS**: Groups handed in their projects. The groups that needed to present started to present. Did not finish presentations.

- **Per 8 Advanced ESS**: Groups handed in their projects. The groups that needed to present started to present. Did not finish presentations.

Wednesday, September 19, 2012

- **Per 3 Academic ESS**: Finished up presentations. This class ended early with about 15 mins left. I let them have a study hall at the end of the period.

- **Per 4 Academic ESS**: Finished up presentations.

- **Per 6 Advanced ESS**: Finished up presentations.

- **Per 8 Advanced ESS**: Continued presentations. All but 1 finished. Will finish tomorrow.

Thursday, September 20, 2012

- **Per 3 Academic ESS**: Had students complete both the self-efficacy survey and the misconceptions survey again. Did not make students fill out the “where did I learn this” section of the misconceptions survey. Started the 3rd section on the SLUG “Fronts”. Had students use def sheets to determine what an air mass was. Gave notes on different types of air masses.
• **Per 4 Academic ESS:** Had students complete both the self-efficacy survey and the misconceptions survey again. Did not make students fill out the “where did I learn this” section of the misconceptions survey. Started the 3rd section on the SLUG “Fronts”. Had students use def sheets to determine what an air mass was. Gave notes on different types of air masses.

• **Per 6 Advanced ESS:** Had students complete both the self-efficacy survey and the misconceptions survey again. Did not make students fill out the “where did I learn this” section of the misconceptions survey. Started the 3rd section on the SLUG “Fronts”. Had students use def sheets to determine what an air mass was. Gave notes on different types of air masses.

• **Per 8 Advanced ESS:** Finished last presentation. Had students complete both the self-efficacy survey and the misconceptions survey again. Did not make students fill out the “where did I learn this” section of the misconceptions survey. Started the 3rd section on the SLUG “Fronts”. Had students use def sheets to determine what an air mass was. Gave notes on different types of air masses.

Friday, September 21, 2012

• **Per 3 Academic ESS:** Quickly reviewed air masses. Had students describe a front using their vocab sheet. Went over cold front and cumulonimbus clouds including hail. Started warm front.

• **Per 4 Academic ESS:** Quickly reviewed air masses. Had students describe a front using their vocab sheet. Went over cold front and cumulonimbus clouds including hail. Started warm front.
• **Per 6 Advanced ESS:** Quickly reviewed air masses. Had students describe a front using their vocab sheet. Went over cold front and cumulonimbus clouds including hail. Started warm front.

• **Per 8 Advanced ESS:** Quickly reviewed air masses. Had students describe a front using their vocab sheet. Went over cold front and cumulonimbus clouds including hail. Started warm front.

• **After school:** Sat down with dept. chair and discussed what I did this week. Talked about the projects. Decided I did not lead them in any direction based on what I did. Talked about the cold fronts lesson. Although some things overlapped with content from the water cycle (Molly) section, I was not leading them, only reinforcing what they learned when needed.

Monday, September 24, 2012

• **Per 3 Academic ESS:** Quickly reviewed cold fronts. Went over different types of clouds. Went over warm front with cloud types including nimbostratus clouds. Assigned a vinn diagram of cold and warm front. They had to finish for homework.

• **Per 4 Academic ESS:** Quickly reviewed cold fronts. Went over different types of clouds. Went over warm front with cloud types including nimbostratus clouds. Assigned a vinn diagram of cold and warm front. They had to finish for homework.

• **Per 6 Advanced ESS:** Quickly reviewed cold fronts. Went over different types of clouds. Went over warm front with cloud types including nimbostratus clouds.
Assigned a vinn diagram of cold and warm front. They had to finish for homework.

- **Per 8 Advanced ESS:** Quickly reviewed cold fronts. Went over different types of clouds. Went over warm front with cloud types including nimbostratus clouds. Assigned a vinn diagram of cold and warm front. They had to finish for homework.

Tuesday, September 25, 2012

- **Per 3 Academic ESS:** Quickly reviewed vinn diagrams. Introduced concept 4 from SLUG “Severe Weather”. Had students work in groups using their books to compare and contrast hurricanes and tornadoes. Went over the group work as a class to get students input and answer questions.

- **Per 4 Academic ESS:** Quickly reviewed vinn diagrams. Introduced concept 4 from SLUG “Severe Weather”. Had students work in groups using their books to compare and contrast hurricanes and tornadoes. Went over the group work as a class to get students input and answer questions.

- **Per 6 Advanced ESS:** Quickly reviewed vinn diagrams. Introduced concept 4 from SLUG “Severe Weather”. Had students work in groups using their books to compare and contrast hurricanes and tornadoes. Went over the group work as a class to get students input and answer questions.

- **Per 8 Advanced ESS:** Quickly reviewed vinn diagrams. Introduced concept 4 from SLUG “Severe Weather”. Had students work in groups using their books to compare and contrast hurricanes and tornadoes. Went over the group work as a class to get students input and answer questions.
Wednesday, September 26, 2012

- **Per 3 Academic ESS:** Reintroduced concept maps again to the class. This time I had students pull two examples of the vocab and as a group had them help start the concept map. Gave them the rest of the period to work on it in pairs. They grasped it better this time. I had to work with a few individuals one on one to help them understand and get started. They worked for the whole period. Did not assign it for homework.

- **Per 4 Academic ESS:** Reintroduced concept maps again to the class. This time I had students pull two examples of the vocab and as a group had them help start the concept map. Gave them the rest of the period to work on it in pairs. They grasped it better this time. I had to work with a few individuals one on one to help them understand and get started. They worked for the whole period. Did not assign it for homework.

- **Per 6 Advanced ESS:** Reintroduced concept maps again to the class. This time I had students pull two examples of the vocab and as a group had them help start the concept map. Gave them the rest of the period to work on it in pairs. They grasped it better this time. They worked for the whole period. Did not assign it for homework.

- **Per 8 Advanced ESS:** Reintroduced concept maps again to the class. This time I had students pull two examples of the vocab and as a group had them help start the concept map. Gave them the rest of the period to work on it in pairs. They grasped it better this time. They worked for the whole period. Did not assign it for homework.
Thursday, September 27, 2012

- **Per 3 Academic ESS:** Today I assigned the Essential questions from the SLUG. They were told to include the vocab into the answers and use complete sentences. Once again I let them work in pairs. They were to finish the concept map first, then the EQ’s. What they did not finish was to be done for homework to review for the test.

- **Per 4 Academic ESS:** Today I assigned the Essential questions from the SLUG. They were told to include the vocab into the answers and use complete sentences. Once again I let them work in pairs. They were to finish the concept map first, then the EQ’s. What they did not finish was to be done for homework to review for the test.

- **Per 6 Advanced ESS:** Today I assigned the Essential questions from the SLUG. They were told to include the vocab into the answers and use complete sentences. Once again I let them work in pairs. They were to finish the concept map first, then the EQ’s. What they did not finish was to be done for homework to review for the test. Most pairs finished the work by the end of the period.

- **Per 8 Advanced ESS:** Today I assigned the Essential questions from the SLUG. They were told to include the vocab into the answers and use complete sentences. Once again I let them work in pairs. They were to finish the concept map first, then the EQ’s. What they did not finish was to be done for homework to review for the test. Most students finished the work before the end of the period.

Friday, September 28, 2012
• **Per 3 Academic ESS:** Collected students’ concept maps and EQ’s. Students took the Meteorology test. The data collection tool questions were built into the test without the confidence ratings. Students did not complete a self-efficacy survey.

• **Per 4 Academic ESS:** Collected students’ concept maps and EQ’s. Students took the Meteorology test. The data collection tool questions were built into the test without the confidence ratings. Students did not complete a self-efficacy survey.

• **Per 6 Advanced ESS:** Collected students’ concept maps and EQ’s. Students took the Meteorology test. The data collection tool questions were built into the test without the confidence ratings. Students did not complete a self-efficacy survey.

• **Per 8 Advanced ESS:** Collected students’ concept maps and EQ’s. Students took the Meteorology test. The data collection tool questions were built into the test without the confidence ratings. Students did not complete a self-efficacy survey.

• **After school:** Sat down with dept. chair and discussed what I did this week. Talked about concept maps. Both agreed that we were pleased the concept maps went better this time. She liked the ideas about assigning the EQ’s because it forced them to review their knowledge. She also agree with me that only being a facilitator for the concept maps and EQ’s rather then going over it as a whole class forced them to use their knowledge and did not lead them to answers to skew my results.