METACOGNITIVE STRATEGIES IN AN

EARTH SCIENCE CLASSROOM

by

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A professional paper submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Science Education

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DEDICATION

For Kase and Alton, my family. Alton, being your mom is the greatest gift. May you forever be curious and in wonder of the world we live in. Kase, our dreams will come true. I love you both.

ACKNOWLEDGEMENTS

I owe a great debt of gratitude to Dr. John Graves. I never expected to be so understood and showered with grace while completing my Master's degree. During times when I was disappointed in myself and felt defeated and overwhelmed, Dr. Graves encouraged me to keep going and press on. I cannot imagine completing this project with any other advisor. Thank you for your patience and encouragement.

Thank you to my students who have been absolutely wonderful. Not only was I completing this project, of which they were my study population, but this was also my first year teaching while being a mom. Needless to say, there were days when I was emotionally absent and "on edge" all day. They adapted to my needs and met me where I was at. I was not expecting a group of 14 and 15 year olds to be so understanding and mature. I am humbled by your care for me.

Finally, thank you to my husband, Kase. How could I have done any of this without you? When you were busy starting your business, you still had time to encourage me to work on this project. You cared for Alton and I when I was overwhelmed and a complete mess. During a time that was so crazy, you still found time for us to dream and plan the life we want to live. You know what makes me happy and you know how to pull me out of my sadness. Without you, none of this would have ever started and I wouldn't be where I am today. I love you.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The purpose of this research was to determine whether teaching about the levels of thinking along with the intentional inclusion of metacognitive strategies would increase the level of thinking of secondary students in an Earth science course. Of secondary interest was the impact of these practices on the confidence level of students. Students first participated in a non-treatment unit where they were not taught about Bloom's Taxonomy or levels of thinking nor were reflections included in their classroom practice. Students took a pre-unit and post-unit Thinking Test, Thinking Survey, and Confidence Survey during the non-treatment unit to determine the normal gain during a unit of instruction. Following the non-treatment unit, students learned about the levels of thinking through direct instruction and classroom activities. Throughout the unit, students reflected on what they learned, how the learned, and practiced writing high level questions about the content they learned that week. Again, the pre- and post-unit Thinking Test, Thinking Survey, and Confidence survey were administered to determine if the treatment had an effect on students' abilities to think at higher levels. The results indicated that students significantly improved their ability to answer higher level questions following treatment. However, no significant difference was found in student confidence. Therefore, the results of this study indicate that learning about the levels of thinking and implementing metacognitive strategies positively influences students' ability to think at and use higher levels of thinking but does not impact student confidence.

INTRODUCTION & BACKGROUND

We live in a world where Google instantaneously answers our questions and our devices tell us how to get to the nearest grocery store. Most kids living in today's world have never known anything different. Students have been taught that answers can be found online, and they do not practice problem-solving skills. They often wonder why they would spend their time doing something someone else has already done. Their perspective is that they should just be told the answer; wouldn’t that be the easiest solution? Their attempt to be efficient is admirable, but a major error lies in this type of thinking. They are assuming that since all things have been answered, why put forth the effort to solve the problem, again? This mindset has a hidden meaning: problem-solving is not a necessary skill to practice. However, some of the fault lies in the education system of which I am a part. Unfortunately, the way we often teach often does not require students to think at higher levels.

The overall lack of higher order thinking among the majority of my 9th grade students has become overwhelmingly apparent in the recent years. Students often ask that if they memorize the study guide, will they get an A on the test. My response is not the one students hope for, but it is the same response I repeatedly give all year long: Memorization is not the point. There is a difference between memorizing and true understanding. You should study concepts, processes, and big ideas and be able to use what we have been learning. It was from these repeated moments that I decided on my topic for this study.

My research was conducted at Grand Haven High School (GHHS) in Grand

Haven, Michigan. Grand Haven is small city on the shores of Lake Michigan. GHHS has approximately 1,900 students in 9^{th}-12^{th} grade. The majority (88%) of students are Caucasian with the next largest ethnicity being Hispanic (6%). Twenty-six percent of students qualify for free/reduced lunch (School Detail, 2018). A one-to-one technology initiative was introduced in the 2015-2016 school year. Each student has a Chromebook that they are given and use at school and bring home daily. Chromebooks can benefit the classroom environment if used responsibly; however, they can also cause students to avoid problem solving and higher order thinking if not managed properly.

In November 2014, Michigan adopted the Next Generation Science Standards (NGSS) with some small changes to include region specific standards (ex: formation of the Great Lakes). With these changes, the standards are referred to as the Michigan Science Standards (MSS). In the spring of 2017, GHHS started training science teachers how to teach in to include the three dimensions of the NGSS. For example, we are teaching scientific modeling, facilitating discussion and argumentation with evidence, and other science and engineering practices (Figure 1). Every high school science teacher is expected to take this training and is expected to require students to think at deeper and higher order thinking levels.

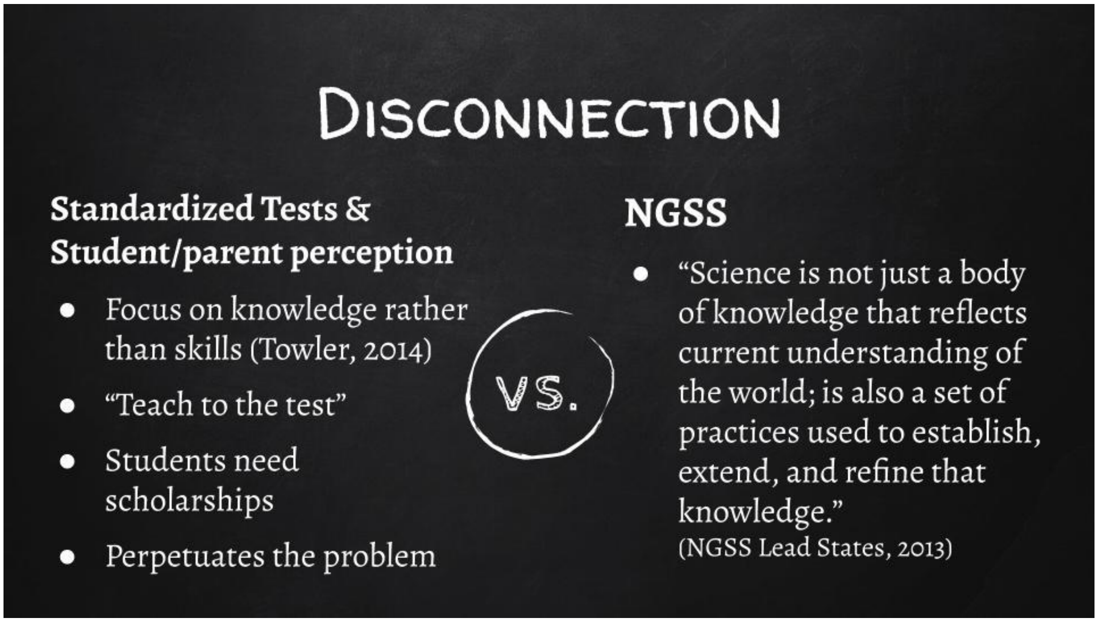

Figure 1. Disconnection between student and school expectations and Next Generation Science Standards Expectations.

Together, the necessity of higher order thinking as part of the NGSS/MSS and the lack of higher order thinking among students exposed a disconnect that needed a solution (Figure 1). I began to wonder how to assist students in practicing these skills. The purpose of this study was to determine if metacognitive strategies result in an increase of students using and displaying higher order thinking. This research also addressed the following sub-question: how will student use of higher order thinking impact their confidence and attitude levels in science?

CONCEPTUAL FRAMEWORK

With Michigan's recent adoption and implementation of the NGSS, many science teachers have been reminded that the goal of teaching science should not be teaching students to recall scientific facts. Rather, teachers' goal should be to create experiences where students will practice scientific problem solving. Michigan's past standards were mostly focused on content knowledge and recall. NGSS, however, clearly emphasizes that students should be able to use the content knowledge not simply recall it (NGSS Lead States, 2013). The National Research Council (2012) stated that “science is not just a body of knowledge that reflects current understanding of the world; it is also a set of practices used to establish, extend, and refine that knowledge. Both elements - knowledge and practice - are essential” (p. 26). Being able to apply and practice knowledge requires students to think at a deeper and higher levels.

When categorizing levels of thinking, Bloom's Taxonomy is an educational staple. The order of thinking levels, from low to high, are as follows: knowledge, understanding, applying, analyzing, evaluating, and creating. The three lowest levels are considered to be lower level thinking as they require recognition and recall. The top three levels are considered higher order thinking because they involve critical and creative thinking (Saido, Siraj, Bin Nordin & Al Amedy, 2015). High-stakes, standardized tests often focus on lower thinking levels, which has exasperated the problem of teaching and learning at lower levels (Towler, 2014). With the implementation of NGSS, however, this trend appears to be changing as higher-level thinking has been added to standardized tests.

Students benefit from teaching and learning at higher levels. When students are challenged to think beyond recognition and recall, they do better on these high stakes tests than students who only practice using low order thinking (Preus, 2012). The significance of teaching and learning at higher levels goes beyond standardized tests. According to Preus (2012), students should also be able to have authentic conversations and be able to make connections to the world outside of the classroom. When students are taught to solve complex problems with critical and creative thinking, they will be more successful in a world full of problems waiting to be solved. Basic knowledge and recall of facts will be necessary, but they will not be enough. High order thinking and deeper learning is the way schools can prepare students to be successful after graduation (Towler, 2014).

A common concern of requiring higher order thinking is that it can only be used for high achieving students (Saido et al., 2015). However, this is not true. Students with disabilities are successfully able to do the same higher order thinking work as general education students (Perus, 2012). Low-achieving students are actually more likely to pursue some sort of post-secondary education if they have practiced higher order thinking (Towler, 2014). Students become aware of their own thinking when they are processing at higher levels. This is a benefit to all students and will inevitably lead to growth (Saido et al., 2015).

This shift to higher order thinking requires both teachers and students to dig deeper and to teach, learn, and think at a higher level. Resnick (1987) explained that higher order thinking does not follow a specified plan, rather it is complex and often results in many solutions. In addition, higher order thinking includes uncertainty and the inclusion of multiple criteria. One who is able to think at a higher level will be able to find meaning in this chaos by self-regulating and putting forth incredible effort.

Kirkwood (2000) explains two of the major elements in developing higher order thinking are modeling and metacognition. Teachers must model and teach what higher order thinking looks like and be clear about expectations for higher order thinking in the classroom (Kirkwood 2000; Preus, 2012; Smith & Darvas, 2017). For students to regulate their own learning, they need to develop metacognitive practices in which they become aware of and reflect on their own thinking. When given a problem, students must be able to determine what is expected of them, develop a strategy for solving the problem, and then reflect on their thinking throughout the process (Smith & Darvasm 2017). Preus (2012) states that to develop metacognitive strategies, teachers can ask students to reflect on how they learned, why they were asked certain questions, and why they might not have understood something. Other ways to incorporate metacognition in the classroom is through self-surveys. When students are able to develop and effectively use metacognitive strategies, their confidence increases which then allows students to be even more apt to take charge of their own learning (Smith & Darvas, 2017).

METHODOLOGY

The purpose of this study was to determine the effects metacognitive strategies and teaching about higher level thinking had on students' ability to use higher order thinking skills as well as student confidence in science. Higher order thinking, in this paper, refers to Bloom's Taxonomy where the low levels of thinking are considered knowledge, understanding, and applying while the high levels of thinking are analyzing, evaluating, and creating (Figure 2).

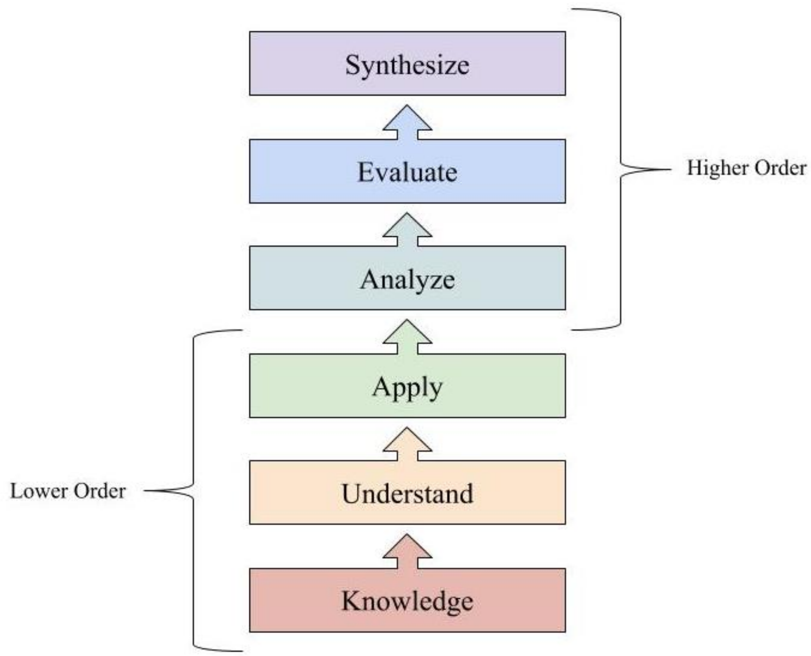

Figure 2. Revised Bloom's Taxonomy with higher and lower order designations.

This study was conducted in two Earth science classes composed of ninth graders (*N*=30). I wanted to know if the explicit teaching of thinking levels and use of metacognitive strategies would improve students' ability to use higher order thinking skills in science. Students in these two classes completed the first unit of the semester, Motion of Water, with no treatment, referred to as the non-treatment unit. This non-treatment unit was used as a comparison for the second unit, Phases of Water in which the treatment was applied. This second unit is referred to as the treatment unit. This method for comparison was necessary as students cannot be expected to use a new learning and thinking technique during the first unit and not use it in subsequent units. Therefore, all students in the study did not experience treatment for the non-treatment unit but participated in the treatment for the treatment unit. Students took the Thinking Test to be used as pre/post comparison for both units (Appendix A). The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix B).

Project Treatment

During the treatment unit and prior to any content being delivered, students were taught the science behind metacognition as well as the different levels of thinking according to Bloom's Taxonomy. Students read and classified statements as either a high or low levels of thinking (Appendix C). As a class, we discussed the best ways how to answer high level questions. Throughout the unit, I reminded students, via modeling, what high order thinking looks and sounds like.

In order to increase their metacognitive skills, students were asked to reflect on their thinking and learning. Weekly reflections allowed students to reflect on their learning from the week. Specifically, students were asked to reflect on their thinking and how they learned rather than simply what they learned. Students were also asked to write at least two high level questions every week.

Data Collection

To determine if students' level of thinking increased post-treatment, students were given the Thinking Test before and after both the non-treatment unit and the treatment unit (Appendix A). The Thinking Test included questions from each level of Bloom's Taxonomy. The same Bloom's verb was used for both tests but replaced with the appropriate content for that unit. For example, the questions, from low to high order asked students to define, explain, use, compare and contrast, evaluate, and hypothesize for both units. The normalized gain was determined for both units for the overall score, the high order questions, and the low order questions by finding the ratio of the observed average gain to the possible average gain. A normalized gain of less than 30% were considered low gains, 30% to 70% were considered medium gains, and greater than 70% were considered high gains (Hake, 1998). The data from the pre- and post-tests for both units were plotted in box and whisker diagrams. Results of the Thinking Test were also analyzed for statistical significance using a Paired t-test. To determine if students' perspectives of their own thought process changed over the course of treatment, students completed the Thinking Survey (Appendix E). The survey was in a Likert scale format. Results were analyzed for statistical significance using a Wilcoxon Signed Rank Test.

Student confidence in science was a secondary question for this study. If students increased their thinking levels, would there also be an increase in confidence levels? To determine this, students were given the Confidence Survey before and after both the non-treatment unit and the treatment unit (Appendix F). The survey was in a Likert format. Students had the option to choose between Strongly Disagree, Disagree, Agree, or Strongly Agree. Each of the choices were given a number (Table 1). Results were analyzed for the frequency of the type of change (increased or decreased) and for statistical significance using a Wilcoxon Signed Rank Test.

Table 1
Likert Response Quantitative Equivalent

Response	Score
Unsure of what this means	0
Strongly Disagree	1
Disagree	2
Agree	3
Strongly Agree	4

At the end of the treatment unit, student interviews were conducted to determine what students perceived about their own thinking and if their confidence in science changed since the beginning of the treatment (Appendix G). The data collection instruments are summarized in the triangulation matrix below (Table 2).

Table 2
Data Triangulation Matrix

Focus Question	Data Source 1	Data Source 2	Data Source 3
Primary Question 1. Does the use of metacognitive strategies result in students using higher order thinking?	Pre- and Post-Thinking Test for non-treatment and treatment units	Pre- and Post-Student Thinking Survey	Post-treatment Student Interviews
Sub Question 2. How will the use of metacognitive strategies influence student confidence in science?	Pre- and Post-Confidence Survey	Post-treatment Student Interviews	

DATA AND ANALYSIS

The results of the Thinking Test indicated that students significantly increased their use of higher order thinking from 27% prior to treatment to 39% post-treatment where they used and learned about metacognitive strategies and higher order thinking ($p < 0.5$, N=30) (Figure 3). The data showed a medium-low normalized gain of 35% prior to treatment (non-treatment unit) and a medium-high gain of 51% following treatment (treatment unit). The normalized gain indicated that students were able to answer 16% more of the higher order questions than they were able to during the non-treatment unit. Students' ability to answer Evaluate questions showed the greatest improvement from having a low normalized gain of 15% prior to treatment to a medium gain of 43% after treatment (Figure 4).

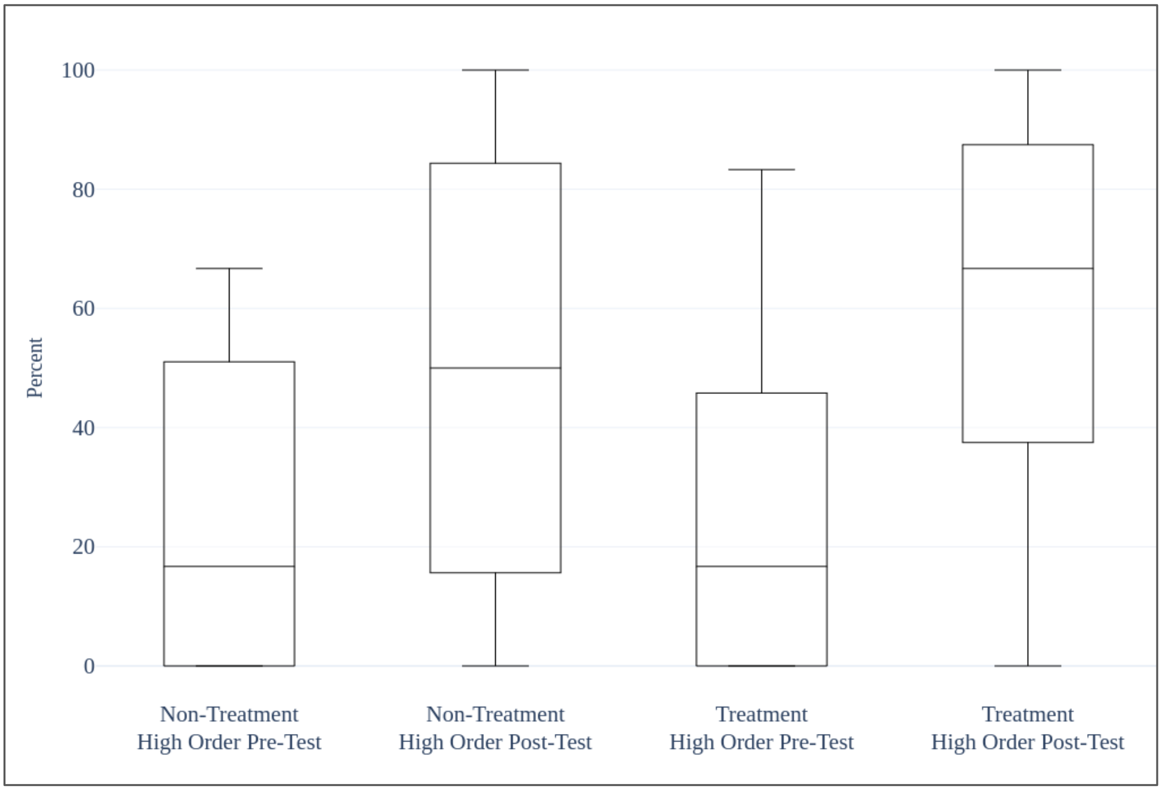

Figure 3. Score distribution of the high level questions from the pre- and post-Thinking Tests for the non-treatment unit and the post-treatment unit, (*N*=30).

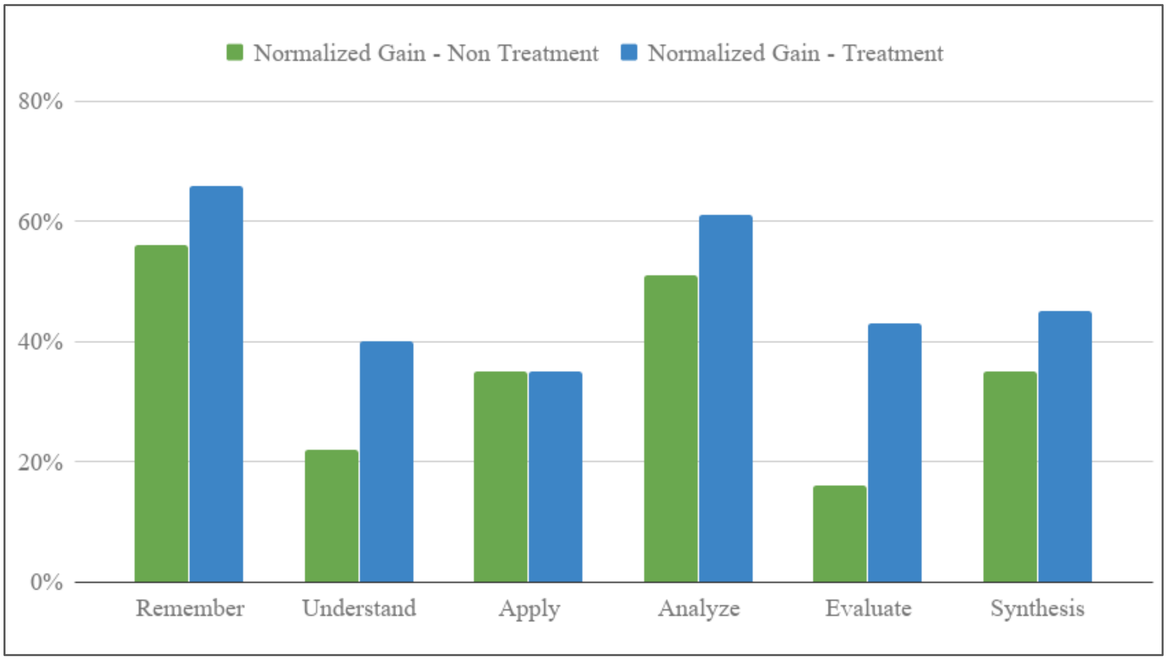

Figure 4. Normalized gains for the thinking levels based on the Thinking Test prior to treatment and post-treatment, (*N*= 30).

The results of the high order statements on the Thinking Survey show that, on average, 19% of students self-reported their ability to use higher order thinking practices increased during treatment, 53% reported no change, and 28% decreased (Figure 5). According to one student, "[learning about the different levels of thinking] made me realize some of the things I was supposed to be thinking about with high levels, I didn't. I was just worried about the surface and not going deep...about the content." When asked if their problem-solving skills have changed after learning to reflect on their own thinking, another student said, "Yes, before, I would get really frustrated if I had a problem that I couldn't figure out, [now] it's a lot easier to figure out how to fix what you need to fix."

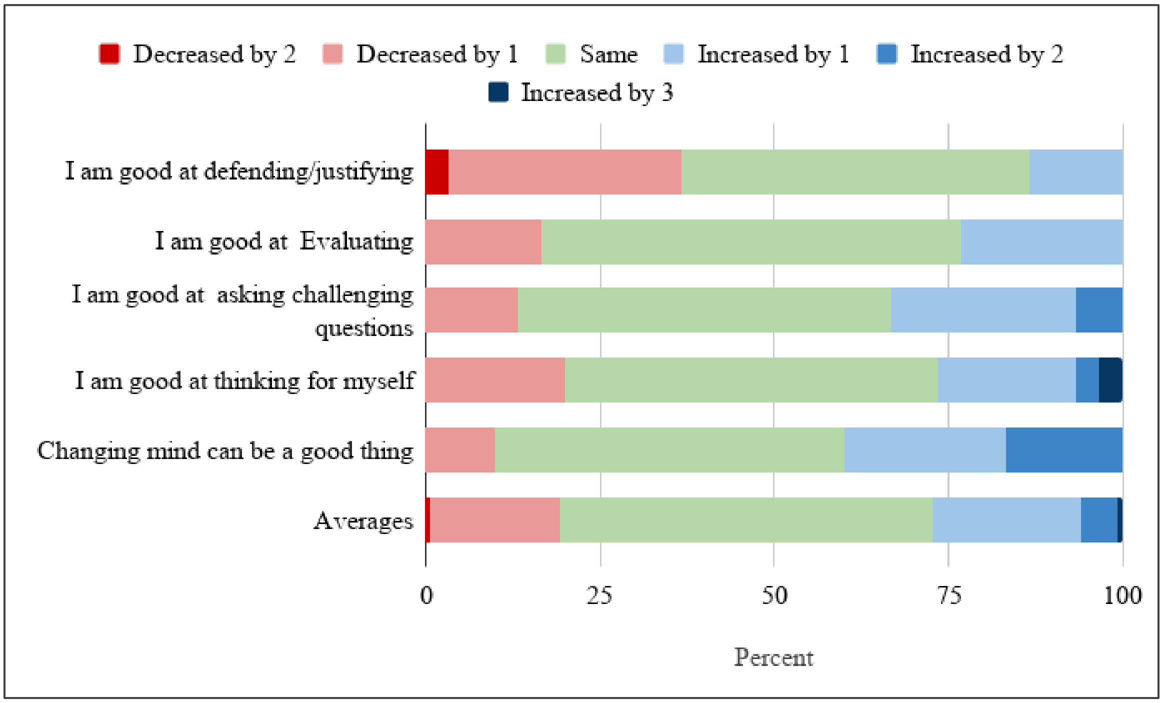

Figure 5. Difference between the pre- and post-Thinking Survey, (*N*= 30).

In addition to an increase in high level thinking in the Thinking Test, the overall Thinking Test score, including both low and high order thinking, significantly improved as well. The results show a 27% increase between pre- and post-Thinking Test prior to treatment and a 41% increase following treatment (Figure 6) ($p<0.05$). The normalized gain for the Thinking Test was 35% for the pre-treatment unit, and 49% for the treatment unit indicating that students were able to answer 14% more of the questions following treatment than they were prior to treatment.

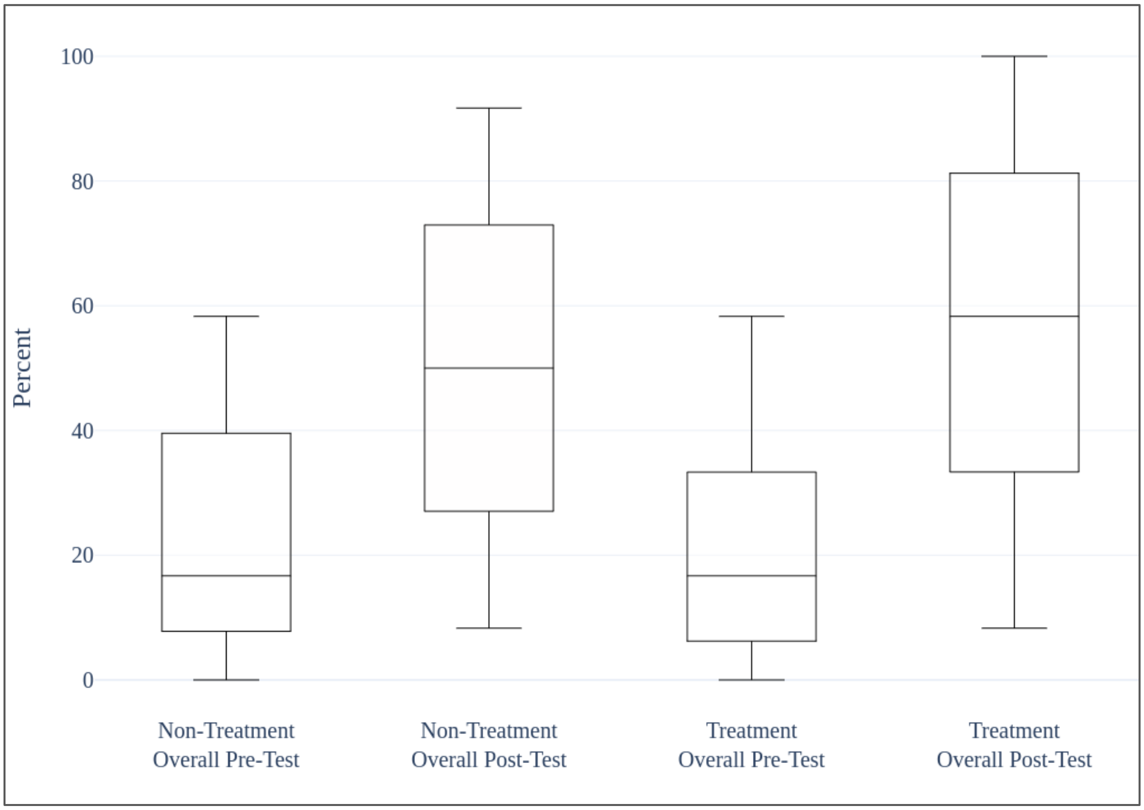

Figure 6. Score distribution of the whole pre- and post-Thinking Tests for the non-treatment unit and the post-treatment unit, (*N*=30).

When asked how studying using high order thinking is different than low order thinking, a student responded, “When you are using higher order thinking…you’re using more of your brain [and] you ask yourself questions when you’re studying, and you don’t when you’re using low order thinking.” Another student stated that “you have to think more in depth of what you learned, and the reflection helps with that. For low order, you just review your notes.” Finally, one more student explained that “low [order thinking] is just defining and memorizing which doesn’t help in the long run…because it doesn’t allow me to think and problem solve as much as high level [thinking].”

The results of the Student Confidence Survey showed that 60% of students’ confidence levels remained the same, 20% indicated their confidence decreased, and 20%

stated their confidence increased (Figure 7). The greatest increase was in students' confidence in reflecting on and thinking about their own thinking; 33% percent of students indicated that their confidence in this skill increased. The greatest decrease was students' confidence in their ability to evaluate where 30% of students indicated that their confidence decreased during treatment (Figure 7). When asked if learning how to use and reflect on higher order thinking changed their perspective on science, one student said, "Yes, because before I didn't really care to understand the reasoning [or] finding evidence for that reasoning, so it made it more interesting to me.

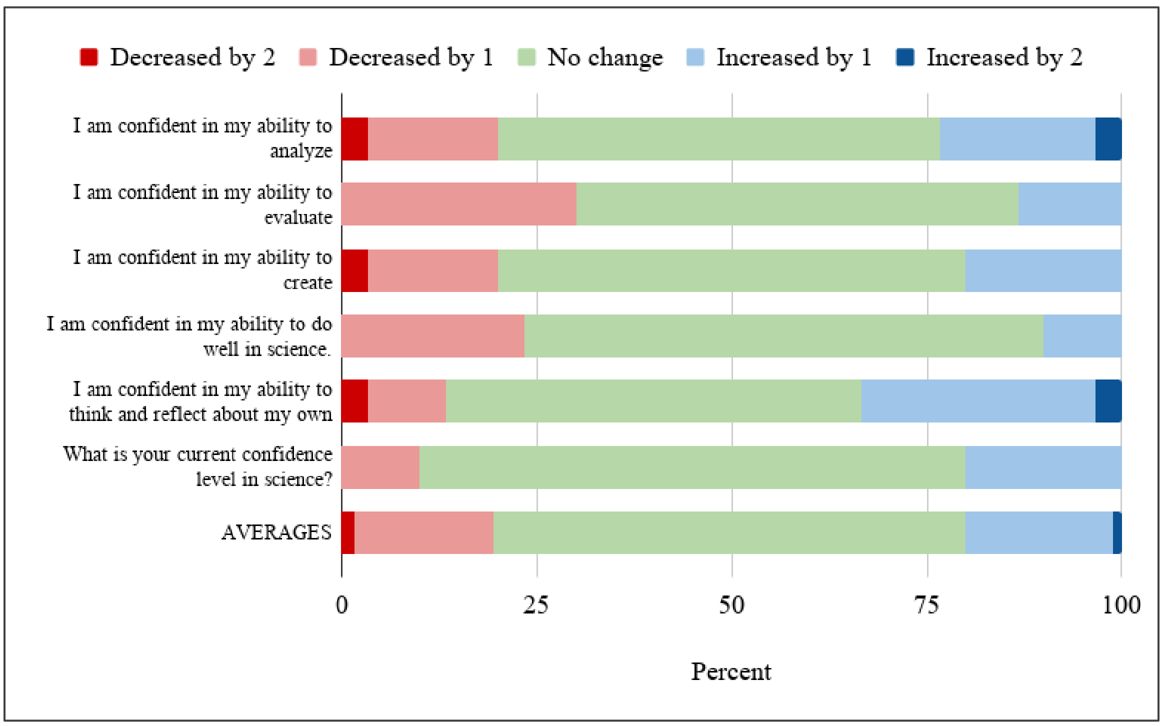

Figure 7. Difference between the pre- and post-Confidence Survey, (*N*= 30).

INTERPRETATION AND CONCLUSION

The purpose for this project was to ultimately develop higher order thinking skills in science by using metacognition and teaching students about the different levels of thinking. Based on the results, the treatment appeared to produce higher order thinking when compared with the non-treatment unit. Since using metacognitive strategies and teaching about higher order thinking, students, overall, have written thorough answers to questions on simple homework assignments, labs, and especially assessments.

When students were completing the pre-test during the non-treatment unit, many students wanted to know what I meant by "evaluate the following statement." I found that statement interesting because I've asked those questions in labs and test throughout the year, but they never actually verbalized what confused them until this pre-test. I also was interested because I gave them the option of choosing a response that indicated that they did not understand what the statement meant. However, I gave this was shown as a zero on the survey. I wonder if simply using a zero deterred students from choosing that option. When analyzing the normalized gains for the Thinking Tests, I was happy to see that the level with the highest gain was the Evaluate level. While grading student responses, it was clear that they had a much better handle on what they needed to do with the question than they did in the non-treatment group. For example, in the non-treatment group, students simply explained what the "evaluate" statement was saying. However, in the treatment group, students chose a side and explained why the statement was right or wrong using their understanding of the content. The Thinking Test data show that students did, indeed, improve in their ability to answer the Evaluate questions, but their confidence does not match these data.

While students did not appear to improve in their confidence in the different levels of thinking, I noticed a positive difference. The way students approach problems is more strategic, and the questions they ask are more for understanding rather than answers. The results of the Confidence Survey surprised me at first. However, I wonder if students did not understand what the words meant when they took the survey prior to treatment. After learning what the different thinking levels required, maybe students realized they actually were not as confident in answering those questions as they originally thought. Prior to treatment, I had a few students ask me the meaning of some words, so I would not be surprised if more students did not understand the question or phrase and decided to choose a response without truly understanding what the response meant. I would have been better to make sure students really understood the meaning of the words prior to doing any sort of assessment or survey.

If I were to go back and make improvements, I would focus on either using metacognition or teaching about thinking levels. At this point, it is difficult to determine what variable actually created the results. I would also put more emphasis on how to write thoughtful and purposeful reflections. Truthfully, the semester in which the research was conducted was difficult because we had eleven snow days between the end of January and February. Students were not able to get into the habit of reflecting frequently and the first unit took nearly two week longer than expected due to the snow days. Students seemed to struggle remembering what they learned when it was divided by multiple snow days. This could have impacted the results.

When I was listening to students talk, I heard from some that they thought the reflections were pointless and a waste of time. At the same time, however, I heard from others that because they needed to stop and think about what they learned, it made the content more concrete and they were able to determine what they did not yet understand. Depending on whether the student took the reflection process seriously or not likely impacted the results and what they gained from it. If there was more time, I would have been able to spend more time modeling the reflective process and metacognitive strategies. I would have also been able to address the value of reflection.

VALUE

This research has been beneficial for both my students and my development as a teacher. Reflective practices have helped me in both my professional and personal life. During my teacher education program, I was taught and learned the value of reflections. I, like many of my students, also first thought that it was a waste of time. However, I began to see the benefits both in my way of thinking and in my mental health! In a world with technology screaming at us from every direction, it is difficult to stop and think, and my students have only known a world with technology, for good and for bad. When doing this research, I noticed that students did not like to stop and think. They wanted to keep going and move on to the next thing. Stopping to think about their thinking and learning seemed like an annoyance to many; it was another box to check. Maybe I did not explain the value enough to them, but maybe it is because they are high school students and enjoying reflection would not be their top priority or maybe it comes from the way technology has taught them to think fast. I wish I would have probed more into this topic during student interviews. It is this overall absence of metacognition, however, that drives me to continue to include a form of reflection in my classroom. Everyone benefits from time to think and to process what and how they learned.

Overall, getting students to slow down reflect about their level of thinking has been beneficial for both student learning and for my teaching. I expected to learn how to teach metacognition and whether or not that would help student learning. However, I didn't expect that I would need to teach what high level questions required of students. I was surprised by how many students asked me what I meant by compare and contrast, evaluate, analyze, and develop. Going forward, I will teach my students what the different levels of thinking are and model good and complete answers. I will also include a reflection piece as part of my classroom expectations. I do not anticipate using such an extensive form as I did during this research, however, because it was too time-consuming which annoyed many students. I would like to see if a more simple and streamlined reflection process can produce the same, if not better, results. This research has provided me the opportunity to take charge of my teaching and choose how to tackle problems I am passionate about.

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APPENDICES

APPENDIX A

THINKING TESTS AND RUBRIC

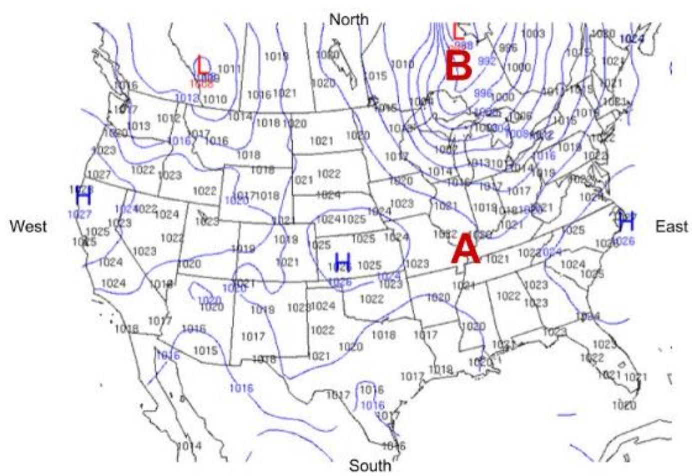
Non-Treatment Unit Thinking Test

Note: Test given via Google Forms

1. Define evaporation

2. Explain the relationship between of each of the listed words below and the movement of water through the water cycle
    a. Condensation
    b. Evaporation
    c. Precipitation
    d. Transpiration

3. Using the map provided, predict the overall wind direction between A and B. Use the format "The wind is moving from ______ to _____" for your answer. Explain how you know.



4. Compare and contrast the troposphere and the stratosphere.

5. Evaluate the following statement:
    a. While it is sad that many people do not have access to freshwater, we are not able to find a solution because some places naturally have freshwater and some naturally do not have freshwater.

6. Hypothesize what would happen, with respect to the water cycle, if a new, big shopping mall was built on what is currently an open field.

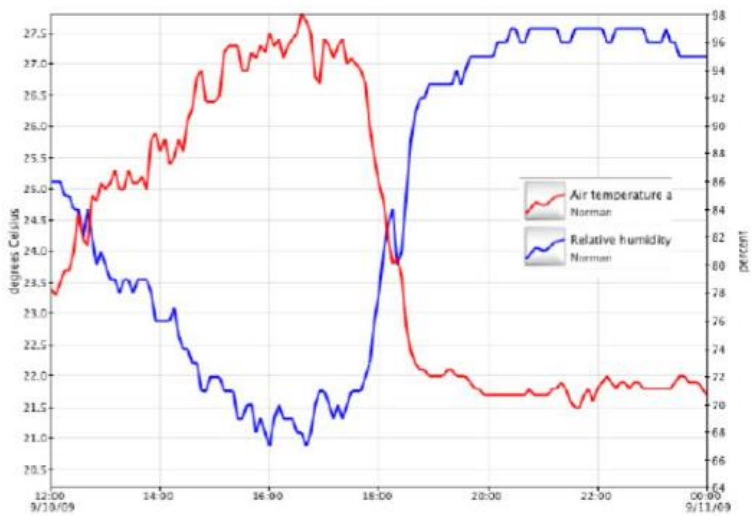
Treatment Unit Thinking Test

Note: Test given via Google Forms

1. Define humidity.

2. Explain the relationship between
    - Humidity
    - Mass
    - pressure

3. Using the data provided, predict what the weather was like at the beginning (12 PM) middle (6 PM / 18:00) and end (8 PM / 22:00). Explain why.



4. Compare and contrast humidity and relative humidity.

5. Evaluate the following statement: Lisa brought an ice cold glass of water outside on a warm summer day and set it on a table while she worked on the garden. When she came back, she noticed the glass was wet on the outside. She thought about it for a minute and decided it must be from the water in the glass since that is the only place she sees water.

6. Hypothesize and explain what would happen to the atmosphere composition if the Earth continues to warm.

Thinking Tests Rubric

	0	1	2
Define	Incorrectly defines	Partially correct definition	Fully correct definition
Explain	Incorrectly explains	Correctly, but only partially explains the relationship OR Incorrectly explains some relationships and correctly explains the others	Correctly explains the relationships between the listed words.
Using	Incorrect answer	Correct answer but not explanation of data	Correct answer and uses the data to support the answer.
Compare and Contrast	Incorrect answer	Correctly compares OR Correctly contrasts the topics	Correctly compares and contrasts the topics
Evaluate	Incorrect answer OR Only explains what the statement means with no evaluation	Explains the good and the bad parts about the statement based on evidence	Take stand and makes a claim on the statement then explains the good and bad parts of the statement in order to support their claim.
Hypothesize	Incorrect answer	Develops a scenario that could happen based on the prompt	Develops a scenario that could happen based on the prompt and supports the scenario with evidence

APPENDIX B

IRB EXEMPTION

INSTITUTIONAL REVIEW BOARD

For the Protection of Human Subjects
FWA 00000165

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MEMORANDUM

TO: Laura Knochenhauer and John Graves

FROM: Mark Quinn, Chair *Mark Quinn CJ*

DATE: December 7, 2018

RE: *"The Influence Metacognitive Strategies have on Higher Order Thinking Skills" [LK120718-EX]*

The above research, described in your submission of December 7, 2018, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

_X_ (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

_X_ (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

____ (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

____ (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

____ (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

____ (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX C

LEVELS OF THINKING STATEMENTS

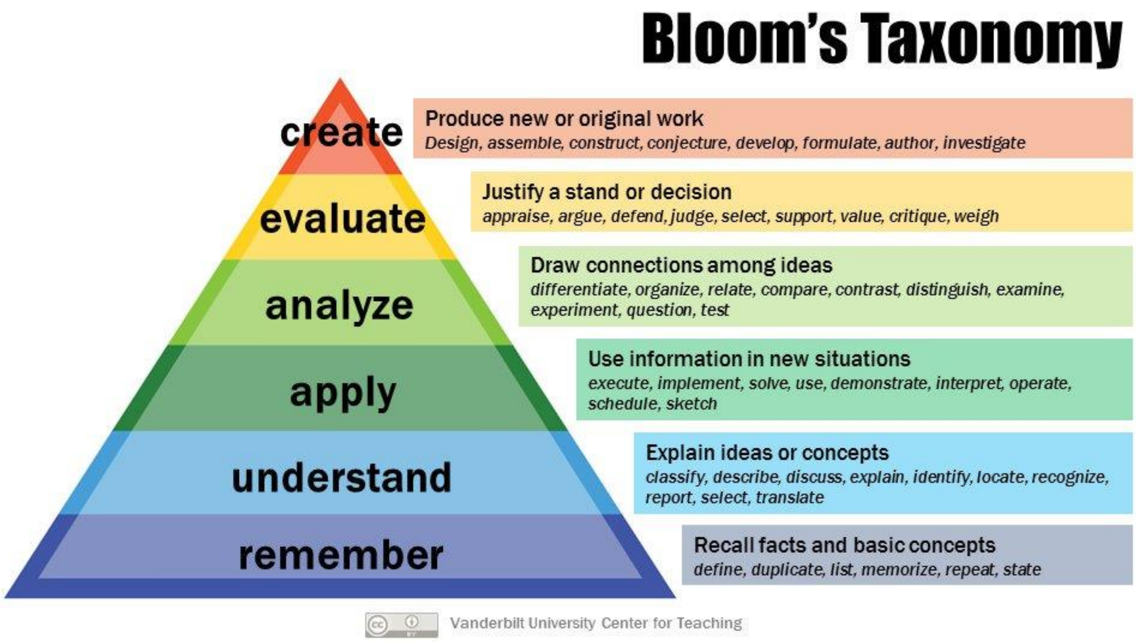
Define albedo.	When was the theory of plate tectonics accepted by the scientific community?
Who proposed the theory of evolution?	List the three types of heat transfer.
How would you compare and contrast the stratosphere and the troposphere?	Summarize the world water crisis.
Interpret the graph.	What would happen if all of the ice caps melted?
How would you use what you learned today to develop a possible solution to the world water crisis?	Based on the lab, what conclusions can you draw about the relationship between the altitude and the atmospheric pressure?
What evidence can you find to support human induced climate change?	Can you distinguish between relative humidity and specific humidity?
What is your opinion of Nestle obtaining the right to pump 400 gallons/minute out of Lake Michigan?	How would you prove the world water crisis is happening today?
What could be done to minimize the negative impacts of Nestle pumping water from Lake Michigan?	What would happen to the Earth and life if humans do not change the way we currently use water and fossil fuels?

Thinking Level Statements Answer Key

1: Remembering Define albedo.	**1: Remembering** When was the theory of plate tectonics accepted by the scientific community?
1: Remembering Who proposed the theory of evolution?	**1: Remembering** List the three types of heat transfer.
2: Comprehension How would you compare and contrast the stratosphere and the troposphere?	**2: Comprehension** Summarize the world water crisis.
2: Comprehension Interpret the graph.	**3: Application** What would happen if all of the ice caps melted?
3: Application How would you use what you learned today to develop a possible solution to the world water crisis?	**4: Analysis** Based on the lab, what conclusions can you draw about the relationship between the altitude and the atmospheric pressure?
4: Analysis What evidence can you find to support human induced climate change?	**4: Analysis** Can you distinguish between relative humidity and specific humidity?
5: Evaluating What is your opinion of Nestle obtaining the right to pump 400 gallons/minute out of Lake Michigan?	**5: Evaluating** How would you prove the world water crisis is happening today?
6: Creating What could be done to minimize the negative impacts of Nestle pumping water from Lake Michigan?	**6: Creating** What would happen to the Earth and life if humans do not change the way we currently use water and fossil fuels?

APPENDIX D

WEEKLY STUDENT REFLECTION DOCUMENT



Week 6 Reflection

1. Of the things we learned this week, what do you feel most confident in? Why do you think this is?
    - ○
2. Of the things we learned this week, what do you feel the least confident in? Why do you think this is? How can you get help with this material (think about <u>all</u> your resources)?
    - ○
3. What do you think you did well this week?
    - ○
4. What could you have done better this week?
    - ○
5. What was something that we did in class that helped you learn something the best? (Don't just think about what was the most fun but what was the most helpful!)
    - ○
6. How can you apply what you learned to different situations?
    - ○
7. Use the image above. High level are the top three sections; low level are the bottom three. Write TWO high level thinking questions from any of this week's material.

APPENDIX E

STUDENT THINKING SURVEY

Student Thinking Survey

Note: Test given via Google Forms

1. **I am good at remembering definitions.**

Strongly Disagree *Disagree* *Agree* *Strongly Agree*

2. **I am good at using what I learned in a new situation.**

Strongly Disagree *Disagree* *Agree* *Strongly Agree*

3. **I am good at defending / justifying my answers to a question.**

Strongly Disagree *Disagree* *Agree* *Strongly Agree*

4. **I am good at evaluating data.**

Strongly Disagree *Disagree* *Agree* *Strongly Agree*

5. **People say I ask challenging questions.**

Strongly Disagree *Disagree* *Agree* *Strongly Agree*

6. **I prefer classes where the teacher does not give the answer but requires me to problem solve and think for myself.**

Strongly Disagree *Disagree* *Agree* *Strongly Agree*

7. **Changing your mind is a sign of weakness.**

Strongly Disagree *Disagree* *Agree* *Strongly Agree*

8. **I always do better in classes where I'm expected to think things out for myself.**

Strongly Disagree *Disagree* *Agree* *Strongly Agree*

9. **I am good at thinking about and reflecting on my own thinking.**

Strongly Disagree *Disagree* *Agree* *Strongly Agree*

APPENDIX F

STUDENT CONFIDENCE SURVEY

Student Confidence Survey

Note: Test given via Google Forms

1. **I am confident in working through a scientific problem I have never seen before.**

Strongly Disagree *Disagree* *Agree* *Strongly Agree*

2. **I am confident in my ability to apply what I've learned to a new situation.**

Strongly Disagree *Disagree* *Agree* *Strongly Agree*

3. **I am confident in my ability to analyze. For example, I am confident in my ability to break information into parts to determine patterns and relationships. I am also confident in analyzing charts or other forms of data to support conclusions.**

Strongly Disagree *Disagree* *Agree* *Strongly Agree*

4. **I am confident in my ability to evaluate. In other words, I am confident in my ability to assess and justify or defend a decision by providing evidence.**

Strongly Disagree *Disagree* *Agree* *Strongly Agree*

5. **I am confident in my ability to create new ideas, products, and solutions. In other words, when faced with a problem, I am confident in my ability to come up with a new and unique solution to solve the problem.**

Strongly Disagree *Disagree* *Agree* *Strongly Agree*

6. **I am confident in my ability to do well in science.**

Strongly Disagree *Disagree* *Agree* *Strongly Agree*

7. **I am confident in my ability to think and reflect about my own thinking.**

Strongly Disagree *Disagree* *Agree* *Strongly Agree*

8. **I intentionally utilize metacognitive strategies to reflect on my personal problem solving processes.**

Strongly Disagree *Disagree* *Agree* *Strongly Agree*

9. **I enjoy science.**

Strongly Disagree *Disagree* *Agree* *Strongly Agree*

10. I enjoy trying to figure out the answer to a difficult problem.

Strongly Disagree *Disagree* *Agree* *Strongly Agree*

11. When given a problem that I've never seen before, but I know about the general topic, I do NOT give up. I slow down, problem solve, and try to figure out the problem using the information I already know.

Strongly Disagree *Disagree* *Agree* *Strongly Agree*

APPENDIX G

STUDENT INTERVIEW QUESTIONS

Student Interview Questions

1. Do you think reflecting on your own thinking and learning has helped you? How?

2. What do you like about thinking about and reflecting your own thinking (metacognition)?

3. What do you dislike about metacognition?

4. Was learning about the different levels of thinking helpful? How?

5. Has your perspective toward science changed after learning how to use and reflect on higher order thinking? Explain.

6. How has your ability to problem solve changed after learning how to use and reflect on higher order thinking?

7. How is studying for a higher order thinking question different than studying for a low order thinking question?

8. In order to become an expert at something, what are some things you would need to do?

9. Do you have anything else you'd like to share with me?