THE EFFECTS OF THE 5E LEARNING CYCLE ON

HIGH SCHOOL SCIENCE STUDENTS

by

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ABSTRACT

In this study, high school Earth science students were taught units on geologic time, oceanography, weather, and meteorology using the 5E learning cycle and traditional teaching methods. Pretest and posttest assessments, delayed posttests, observations, student interviews and pre- and post- TOSRA surveys were used to determine how the 5E learning cycle affects high school students. Results of this study suggested that there was no significant difference between outcomes of the two teaching methods. However, students seemed to enjoy the inquiry approach of the 5E learning cycle.

INTRODUCTION AND BACKGROUND

Context of the Study

Keystone Junior - Senior High School is a rural school located in Knox, Pennsylvania with 475 students enrolled. Thirty-seven percent of students are classified as economically disadvantaged and 12.6% receive special education services within the district. One goal of our district is to raise the scores on the Pennsylvania System of School Assessment (PSSA) exams and Pennsylvania Keystone exams. In the 2018 – 2019 school year 57.9% of Keystone Junior/ Senior High School students scored either proficient or advanced on their state science exams. The statewide goal is to have 83% of students proficient or advanced by the year 2030 (PDE, 2018).

I currently teach Earth and Space Science, which includes students from ninth to twelfth grade. In this class I teach a variety of topics including Earth processes, history of the Earth, meteorology, climatology, plate tectonics, and space. I teach four sections of this class, two of which are considered academic level and two are basic level classes. While teaching these students I have noticed they have difficulty retaining information, staying engaged, and have varying opinions on science.

I have had students' complete pretests and posttests as part of my Student Performance Measure (SPM) that goes into my formal evaluation. While analyzing the data from these pre and posttests it became evident that most students do not retain information over a few short months in class. This fact may be part of why our school's state science test scores are so low. Due to this it is vital for students to retain information from their science classes and be able to apply it to new scenarios over a long time.

Student engagement is another issue faced by many teachers within our district. During my student teaching and my time observing teachers within my current district the only teaching method I learned was the traditional method in which students were lectured for part of the class then completed an activity. I began teaching my own classes in this format and had begun to realize that many students did not respond well to this method. In response to this observation, I have been attempting to find innovative ways to teach my class to engage all students and prevent off task, distracting behaviors. This lack of engagement could also have led to students' negative perceptions of science class and science overall. I am also interested in examining how the implementation of the 5E learning cycle will affect how students perceive science.

The 5E learning cycle was briefly mentioned in one of my undergraduate education classes, but it did not pique my interest until I learned about it in more detail during the Inquiry through Science & Engineering Practices class (MSSE 501) in the summer of 2020. Following this class, I began to implement a few lessons that followed the 5E learning cycle. I started by teaching a lesson on acids and bases that I wrote for a project in MSSE 501. During this lesson students were actively engaged and were thrilled to learn about acids and bases as they explored the color changing properties of red cabbage juice. The outcome of this lesson excited me and inspired me to do more. Unfortunately, with the constantly changing instructional models during the 2020 - 2021 school year it was difficult to plan many other 5E lessons until about halfway through the year. For this, I implemented a complete 5E unit that focused on the history of the Earth. I had many students tell me following this lesson how much they enjoyed the activities and how clear the information presented in the lessons was to them and encouraged me to study the 5E lesson cycle more in depth.

Focus Question

My focus question was, What are the affects of the 5E learning cycle on high school science students?

CONCEPTUAL FRAMEWORK

Constructivist Theory

Constructivist theory explains how students build knowledge through experiences and reflection. A constructivist classroom requires a teacher to modify their instructional practices to be student centered. To do this, teachers must model tasks to build a conceptual model of a process, coach students to give feedback or hints, scaffold lessons to guide students, help students articulate what they are learning through reflections, and push students to explore solutions to real world problems (Zareen, Kayani, & Kayani, 2014). In completing these tasks teachers ask all students to develop their own understandings by fitting new knowledge into what they already know through active learning. Active learning consists of experimenting and solving real-world problems. During these active learning experiences students may encounter information that challenges their previous knowledge. If this occurs, students must reevaluate and change their prior understanding to incorporate this new information. In a classroom that supports the constructivist model the teacher acts as a facilitator who guides small groups of students through the learning process (Bada, 2015). One teaching practice that fosters the ideas of constructivist theory is inquiry-based learning (Llewellyn, 2014).

Inquiry-Based Learning

The inquiry process is best defined as a group of activities that requires students to make observations, ask questions, perform research, gather and interpret data, propose answers, and communicate results of their research (National Research Council, 1996). The inquiry process is a six-step process in which students are actively engaged in the processes of science (Figure 1).

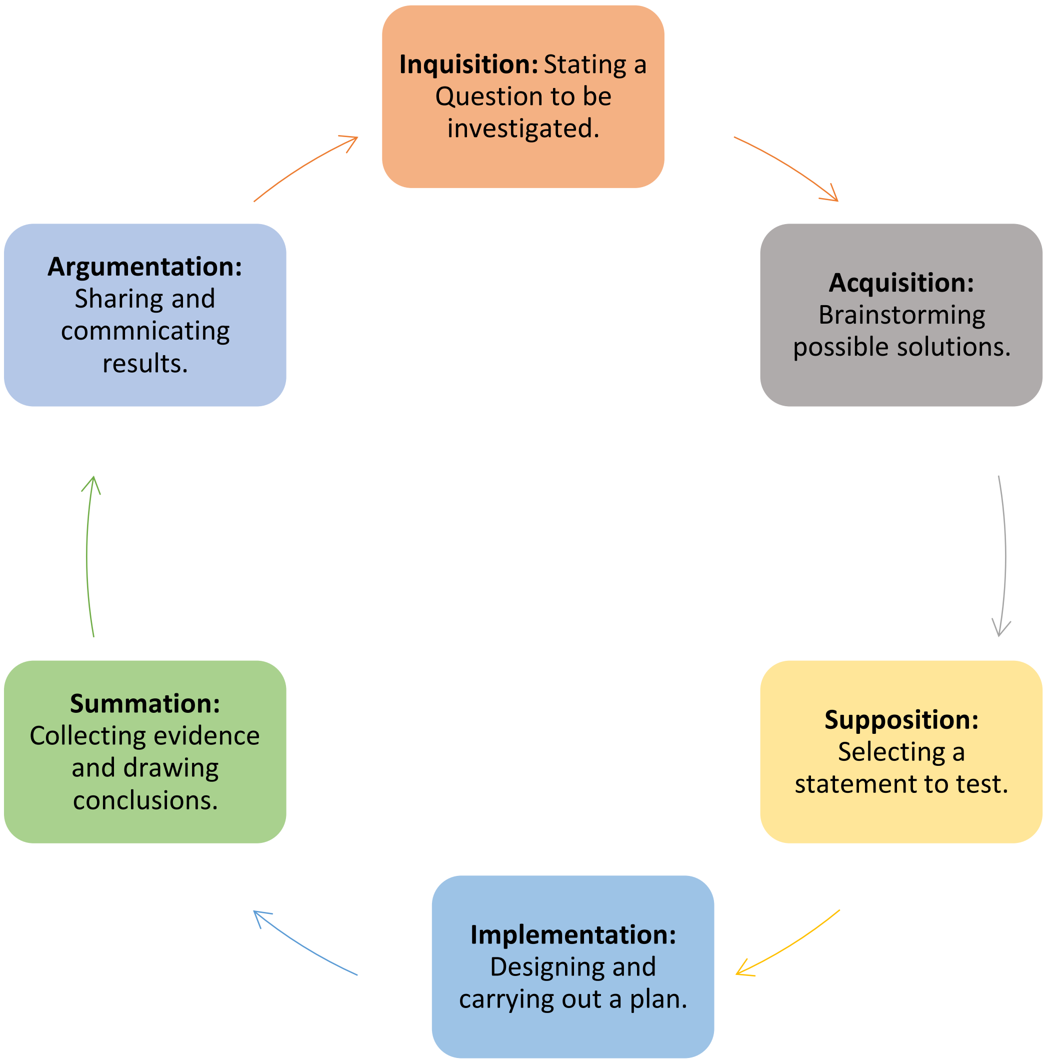

Figure 1. The inquiry cycle (Llewellyn, 2014).

In the first stage of the inquiry cycle, the inquisition phase, the students generate what if questions that drive the rest of the process. In the acquisition phase students use their previous knowledge to develop possible answers to their questions. Students generate hypotheses in the supposition phase. Next, students design and perform an experiment to test their hypothesis. After testing their hypothesis, students collect evidence and interpret the data to answer their question. The final stage of the inquiry cycle is the argumentation stage. In this stage, students share their results supported by experimental evidence (Llewellyn, 2014).

Inquiry-based learning is driven by the curiosity of students which promotes student engagement and learning. The six processes in the inquiry cycle help students learn to generate questions and brainstorm possible solutions, allow them to record observations and data, and encourage them to communicate their thoughts while supporting them with evidence. Overall, the inquiry process develops students into independent thinkers who are lifelong learners. One teaching model that fosters the ideas of inquiry-based learning is the 5E learning cycle (Llewellyn, 2014).

5E Learning Cycle

In the late 1980s, the Biological Studies Curriculum Study (BSCS) began the development of a revised elementary (K-6) science curriculum. The previous curriculum was written in the 1960s and was based on lecturing, textbook readings, and demonstrating science concepts. The Biological Studies Curriculum Study attempted to modify instructional practices based on new research findings into how students learn. The prior instructional model became outdated as researchers continued to develop new understandings of the learning process. It was clear that students hold misconceptions about science. These misconceptions must be challenged, and time allowed for students to build new explanations (Bybee & Landess, 1990).

The 5E learning cycle emerged from the Biological Science Curriculum Study curriculum, and currently aligns with constructivist practices. The 5E learning cycle strives to reach all students and it does this in two ways. First, it requires that all students build on their previous knowledge and, second, it allows a chance for cooperative learning within the science classroom. The prior knowledge students build upon does not have to be from classroom experiences but incorporates any ideas derived from previous observations and experiences (Bybee & Landess, 1990).

To promote learning amongst all students, the 5E teaching model is divided into five phases: Engagement, Exploration, Explanation, Elaboration, and Evaluation (Bybee et al., 2006) (Table 1).

Table 1. Explanations of each phase of the 5E learning cycle (Bybee et al., 2006, p. 2).

Phase	**Explanation**
Engagement	The teacher or a curriculum task accesses the learners' prior knowledge and helps them become engaged in a new concept through the use of short activities that promote curiosity and elicit prior knowledge. The activity should make connections between past and present learning experiences, expose prior conceptions, and organize students' thinking toward the learning outcomes of current activities.
Exploration	Exploration experiences provide students with a common base of activities within which current concepts (i.e., misconceptions), processes, and skills are identified, and conceptual change is facilitated. Learners may complete lab activities that help them use prior knowledge to generate new ideas, explore questions and possibilities, and design and conduct a preliminary investigation.
Explanation	The explanation phase focuses students' attention on a particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviors. This phase also provides opportunities for teachers to directly introduce a concept, process, or skill. Learners explain their understanding of the concept. An explanation from the teacher or the curriculum may guide them toward a deeper understanding, which is a critical part of this phase.
Elaboration	Teachers challenge and extend students' conceptual understanding and skills. Through new experiences, the students develop deeper and broader understanding, more information, and adequate skills. Students apply their understanding of the concept by conducting additional activities.
Evaluation	The evaluation phase encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the educational objectives.

5E Learning Effects on Students

Student Academic Achievement

The 5E learning cycle has been shown to affect students' academic achievement, long-term content knowledge retention, and student engagement. The effects of the 5E learning cycle on student academic achievement were examined in a first-year college-level physics class. This study compared two groups of 30 students, one group taught with traditional teaching methods, and another taught with the 5E learning cycle. Both groups were administered the same pretest and posttest to compare how their knowledge grew through a unit on movement and forces. There was no statistically significant difference between the pretests of the two groups however a difference was discovered after looking at the posttest scores of the two groups. It was found that the 5E learning cycle group had a higher average score on their posttest than the control group meaning those students showed a higher academic achievement (Açışlı et al., 2011).

Another study by Omotayo and Adeleke (2017) examined the effects of the 5E learning cycle on mathematics students who were divided into two groups. A pretest and posttest were administered to each group, 5E and control, and the results were analyzed to determine which group showed the most improvement. They believed that the 5E instructional approach was effective since it allowed students to be actively engaged in every step of their learning process.

Student Engagement

In another study the teaching practices of a science educator in a small private school who developed their own version of the 5E learning cycle was examined. In elementary classes, grades one through six, students were presented with a new concept. They then, explored the concept through discussions and experiments, and conclude the units with a final project. The teacher found that students were more engaged in scientific discussions and practiced better scientific questioning (Beeth & Hewson, 1997).

Content Knowledge Retention

A study of biology students discovered that hands-on learning, such as the 5E learning cycle, prolonged knowledge retention when compared to passive learning. This study compared knowledge retention rates of students who were taught using lecturing, concept mapping, cooperative learning, and the 5E learning cycle. It was found that the students taught with the passive lecturing model scored the lowest on a delayed posttest while the students in the 5E learning cycle group and cooperative learning group scored higher on the delayed posttest. It is proposed this was most likely due to the increased number of hands-on activities and peer interactions in those instructional styles (Ajaja, 2013). Hands-on experiences help students learn and retain information because they can connect their current learning to previous knowledge (Kolb & Kolb, 2005). This hands-on learning also helps students retain the information to be used later, due to the connections to previous knowledge (Ajaja, 2013).

METHODOLOGY

Demographics

With 475 students enrolled, Keystone Junior - Senior High School is considered a small school located in Knox, Pennsylvania. Thirty-seven percent of students are classified as economically disadvantaged and 12.6% receive special education services within the district. The student population is 97% Caucasian students and the remaining 3% is a mixture of African American and Hispanic students (PDE, 2018). In my Earth and Space science classes I am teaching 53 students and four of those individuals have an Individualized Education Plan (IEP).

Treatment

This study was designed to examine the effects of the 5E instructional model on student growth, content knowledge retention, engagement, and attitudes toward science. Throughout this study students completed a total of four units in the curriculum. Each unit took approximately one month to complete. The four Earth and Space Science classes were randomly assigned into one of two groups. While one group learned using 5E instructional model the other group learned the same content using traditional learning methods. After the completion of a unit the instructional methods were switched between the groups so that each group experiences both instructional methods. During traditional instruction, students learned using textbook readings, textbook questions, lectures, and cookbook labs. The 5E instructional group learned concepts using inquiry labs, discussions, and projects. Each group of students completed the same assessments at the end of each unit. The research methodology for this project received an exemption from the Montana State University's Institutional Review Board, and compliance for working with human subjects was maintained (Appendix A).

Data Collection and Analysis Strategies

To determine a baseline of student knowledge a pretest was administered before each unit: Geologic Time Pretest, Oceanography Pretest, Weather Part 1 Pretest, and Weather Part 2 Pretest. A mirrored posttest was administered after the completion of a unit to gauge student growth. These pretests and posttests consist of nine or ten multiple choice questions and one open ended question. After the completion of both the pretest and posttest the normalized gain was calculated for each student. The normalized gains between the treatment group and nontreatment groups were compared. A t-test comparison between the normalized gains of the two groups was calculated to determine if there was a difference in student growth.

To compare student content knowledge retention, a delayed posttest was administered for each unit two weeks after the completion of the unit exam. This delayed posttest was identical to the pretest/ posttest completed for each unit. Normalized gains were calculated for each groups' delayed posttests and a t-test comparison between the normalized gains between groups was run to determine if there was a difference in their knowledge retention (Appendices B, C, D, & E).

The McCollough Science Engagement Tally Sheet was used to determine which teaching technique produced a higher student engagement rate. Throughout the implementation of this project both groups of students were observed four times, twice during the 5E lessons and twice during the traditional teaching lessons. Colleagues or administrators observed the groups and filled in the engagement tally sheet to track behaviors: playing with objects, calling out, talking to peers during inappropriate times, noise making, sleeping, off task Chromebook use, cell phone use and redirection from the teacher. Once all observations were completed, the occurrences of each behavior were tallied and compared between the two teaching styles (Appendix F).

Before students completed any lessons that were part of this project, all students completed a Test of Science Related Attitudes (TOSRA) survey. The TOSRA is forty-two questions designed to determine their opinions on how science affects society, their personal enjoyment of science class, their interests in a career in science, and their interests in science outside of school. After each group completed their first 5E unit they completed the same TOSRA survey again to examine how the 5E lesson plan affected their views on science. The results of each TOSRA survey, both before and after, were examined by finding the mean of each of the seven TOSRA categories. The before and after TOSRA scales were compared to measure how student attitudes changed after experiencing the 5E learning cycle. Paired t-tests were completed to determine if there was a difference between the overall TOSRA scores before and after the 5E lesson. Paired t-tests were also completed to determine if there was a difference between each of the TOSRA categories (Appendix G).

When all units were completed, six students from each group were interviewed with questions on the McCollough 5E Science Interview Questionnaire. To choose these six students I examined the first semester grades and chose two high achieving students, two middle achieving students, and two low achieving students. The interview questions were designed to obtain the opinions of the learners on which units they believed they learned the most during, were most engaged during, and which were their favorite. Student quotes were examined and grouped to determine the percentage of students who preferred each type of learning as well as the percentage of students who liked each unit (Appendix H) (Table 2).

Table 2. Data Triangulation Matrix.

Question	Data Source #1	Data Source #2	Data Source #3	Data Source #4	Data Source #5
What are the effects of the 5E learning cycle on high school science students?	Pretest/ Posttests	Delayed Posttests	Observations	TOSRA Survey	Interviews

DATA ANALYSIS

Pretest and Posttest Analysis

The normalized gains were calculated to determine differences in student knowledge between pretests and posttests (Geologic Time Pretest and Posttest, Oceanography Pretest and Posttest, Weather Part 1 Pretest and Posttest, and Weather Part 2 Pretest and Posttest). On the Geologic Time and Fossils Pretest and Posttest the 5E group had 82% of students show high normalized gains of 0.7, 9% of students with medium normalized gains between 0.3 and 0.7, and 9% or students with low normalized gains of less than 0.3 (Hake, 1998). The 5E group pretest had a range of 82%, a median score of 41%, and half of the students' scores fell between 27% and 55%. The range of scores obtained by the 5E group on their posttest was smaller at 36%. The median score of those students was 88% with half of the students scoring between 82% and 100% (Figure 2). A paired t-test was run between the pretest and posttest scores of the 5E group. The t-test reported a p-value of < 0.0001 resulting in a rejection of the null hypothesis which shows there was a significant difference between the scores.

On the Geologic Time and Fossils Pretest and Posttests, the traditional learning group had 79% of students with high normalized gains of 0.7, 16% with medium normalized gains between 0.3 and 0.7, and 5% with low normalized gains of less than 0.3. On the pretest the traditional learning group had a 91% difference between their highest and lowest scores. The median score for this group was 43% with half of the students scoring between 27% and 52%. After the completion of the geological time and fossils unit the traditional learning group reduced their range of scores to 45%. The median test score increased to 89% and the interquartile range became smaller with fifty percent of students earning scores between 82% and 100% (Figure 2).

A paired t-test was completed between the traditional learning pretest and posttest scores which showed a p-value of < 0.0001 resulting in the rejection of the null hypothesis. This means there was a significant difference between the pretest and posttest scores of the traditional learning group. An unpaired t-test was completed on the posttest scores to compare the 5E learning group and traditional learning group was calculated and a p-value of 0.43 which leads to a failure to reject the null hypothesis meaning that there is no significant difference between the posttest scores of the two groups.

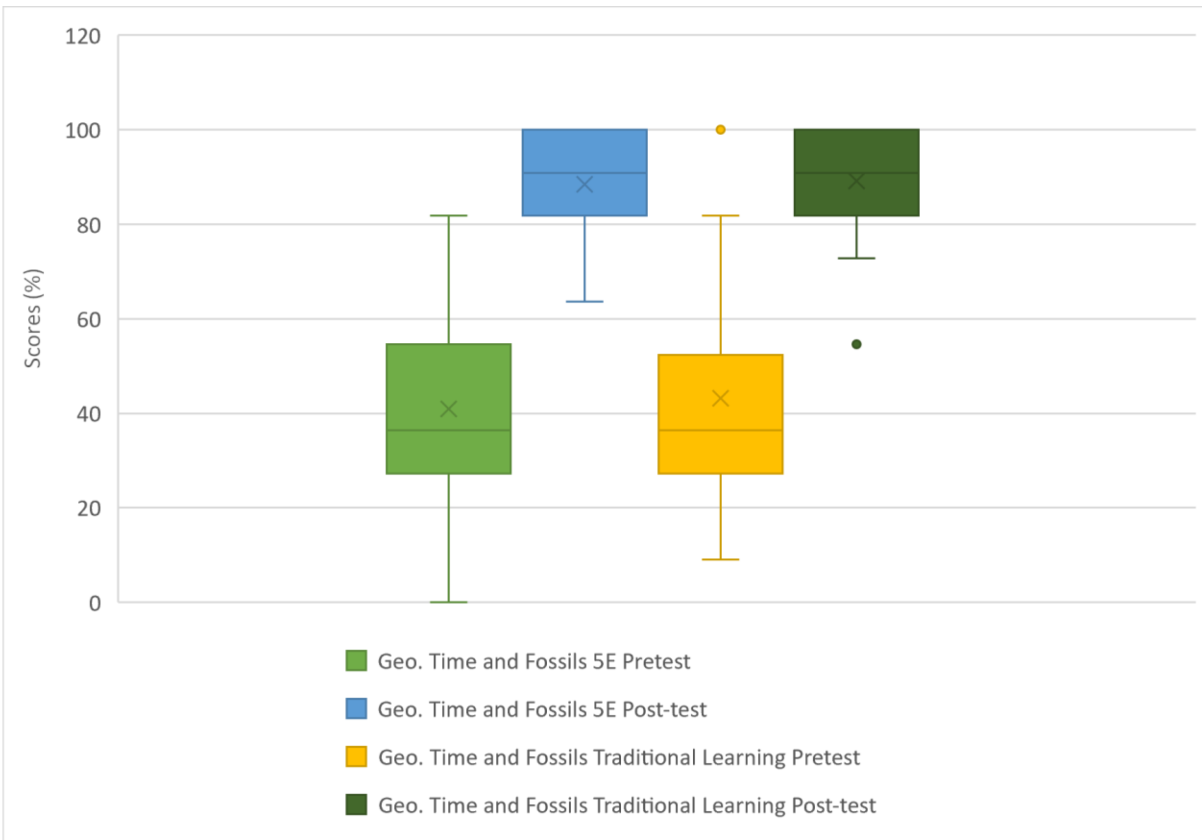

Figure 2. A comparison of the pretest and posttest scores of students who took the geologic time and fossils test, (*N*= 42).

On the Oceanography Pretest and Posttest, the 5E group had 39% of students show high normalized gains of greater than 0.7, 28% of students show medium normalized gains between

0.3 and 0.7, and 33% or students show low normalized gains of less than 0.3. The median score of this group was 37% and the range was 55% with fifty percent of the students scoring between 25% and 45% on the pretest. The students earned an average score of 68% with half of the students earning scores between 45% and 91% and a range of 73% on the oceanography posttest (Figure 3). A paired t-test resulted in a p-value of < 0.0001 leading to the rejection of the null hypothesis meaning that there was a significant difference between pre and posttest scores of this group.

The traditional learning group had 27% of students show high normalized gains of greater than 0.7, 36% of students with medium normalized gains between 0.3 and 0.7, and 36% with low normalized gains of less than 0.3. This group had an average of 33% and a range of 55% on the oceanography pretest. Fifty percent of the students in this group scored between 18% and 45%. On the posttest the traditional learning group increased their average score to 66% and increased the range to 73%. The interquartile range also increased to between 45% and 82%. A p-value of less than 0.0001 was found using a paired t-test between the pretest and posttest scores of the traditional learning group meaning that the null hypothesis was rejected (Figure 3). An unpaired t-test was run between the posttest scores of the 5E and traditional learning group leading to a p-value of 0.39 leading to a failure to reject the null hypothesis.

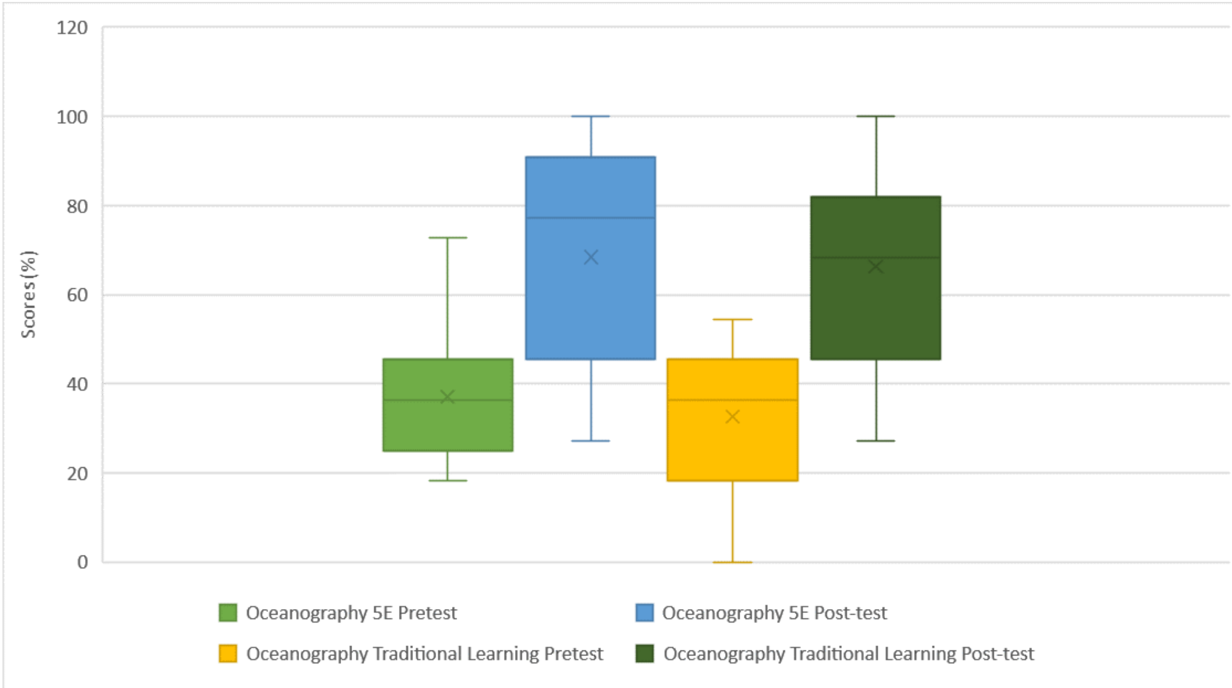

Figure 3. A comparison of the pretest and posttest scores of students who took the oceanography test, (*N*=40).

On the Weather Part 1 pretest and posttest a median score of 48% was earned by the 5E group on the first weather unit pretest. This group had a range of 80% and the interquartile range was between 30% and 60%. On the posttest the 5E group increased their average score to 89% and the range of scores was cut in half to 40%. The interquartile range decreased to the point where half of the students scored between 80% and 95% (Figure 4). It was found that there was a significant difference between the pretest and posttest scores of the 5E group meaning that the null hypothesis was rejected due to a p-value of < 0.0001. A total of 71% of students from the 5E students showed high normalized gains of greater than 0.7, 14% of the 5E students showed medium normalized gains between 0.3 and 0.7, and 14% of students showed low normalized gains of less than 0.3.

In the traditional learning group, 52% of students showed high normalized gains of greater than 0.7, 38% of students showed medium normalized gains between 0.3 and 0.7, and 10% of students showed low normalized gains of less than 0.3. The range of scores was 70% for the pretest of the traditional learning group with half of the students scoring between 20% and 65% and an average score of 42%. On the posttest fifty percent of the students scored between 72.5% and 92.5% and the range was smaller than the pretest at 45%. The average score on the posttest for this group also increased to 81% (Figure 4). A paired t-test of the pretest and posttest scores of the traditional learning group resulted in the rejection of the null hypothesis due to a p-value of < 0.0001. Then, a t-test was performed on the posttest scores of both the 5E and traditional learning groups resulted in a p-value of 0.23 leading to the failure to reject the null hypothesis.

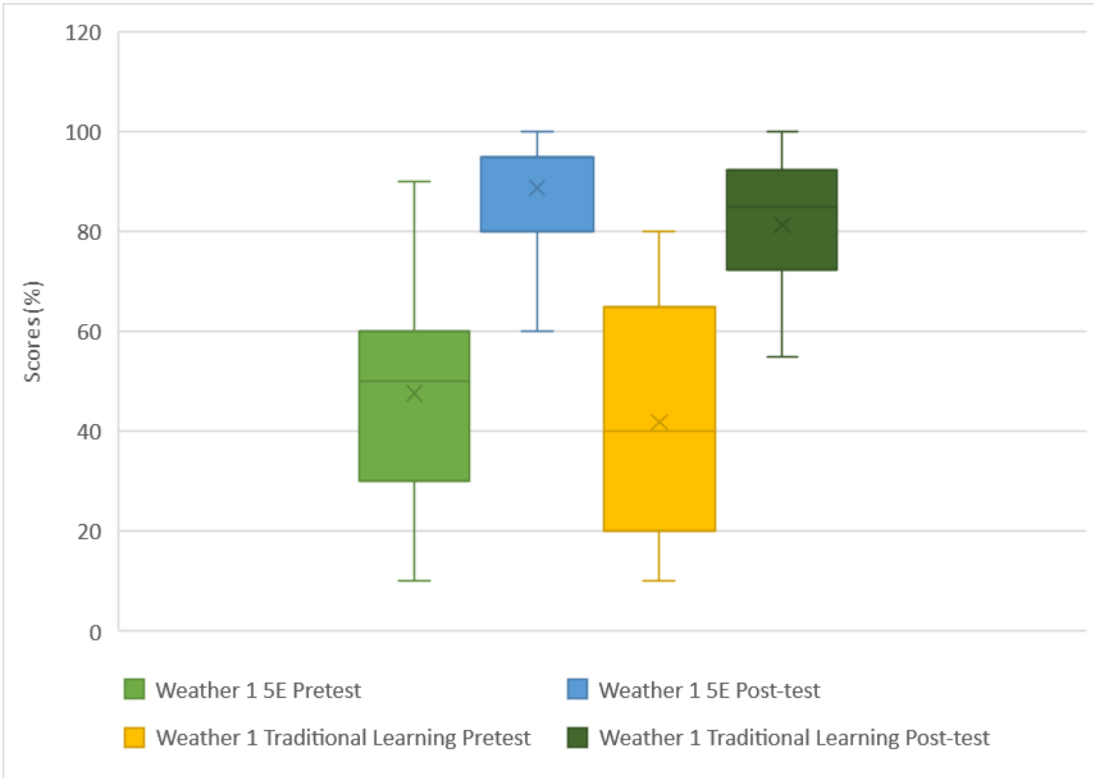

Figure 4. A comparison of the pretest and posttest scores of students who took the Weather Part 1 Test, (*N*=42).

On the Weather Part 2 Pretest and Posttest the 5E group had 32% of students show high normalized gains of more than 0.7, 41% show medium normalized gains between 0.3 and 0.7, and 27% show low normalized gains of less than 0.3. The average score on the pretest of the 5E group was 34% and there was a difference of 70% between the highest and lowest test scores. On this pretest half of the students scored between 20% and 40%. After the completion of the unit half of the students scored between 58% and 80% while there was a range in test scores of 50% and the average test score was 67% (Figure 5). A paired t-test resulted in a p-value of < 0.0001 leading to the rejection of the null hypothesis.

The traditional learning group showed 52% with high normalized gains of 0.7, 38% with medium normalized gains between 0.3 and 0.7, and 10% with low normalized gains of less than 0.3. The traditional learning group started with an average score of 33% on their pretest for the second weather unit with a difference of 65% between their highest and lowest scores and an interquartile range between 28% and 45%. The posttest average score in the traditional learning group increased to 74% and the interquartile range also moved up to between 50% and 90%. However, the range of student scores increased to 70% on the posttest (Figure 5). Through a paired t-test of these scores a significant difference was found with a p-value of < 0.0001. Another unpaired t-test was performed to determine if there was a difference between the 5E and traditional learning groups. A p-value of 0.12 was found leading to a failure to reject the null hypothesis.

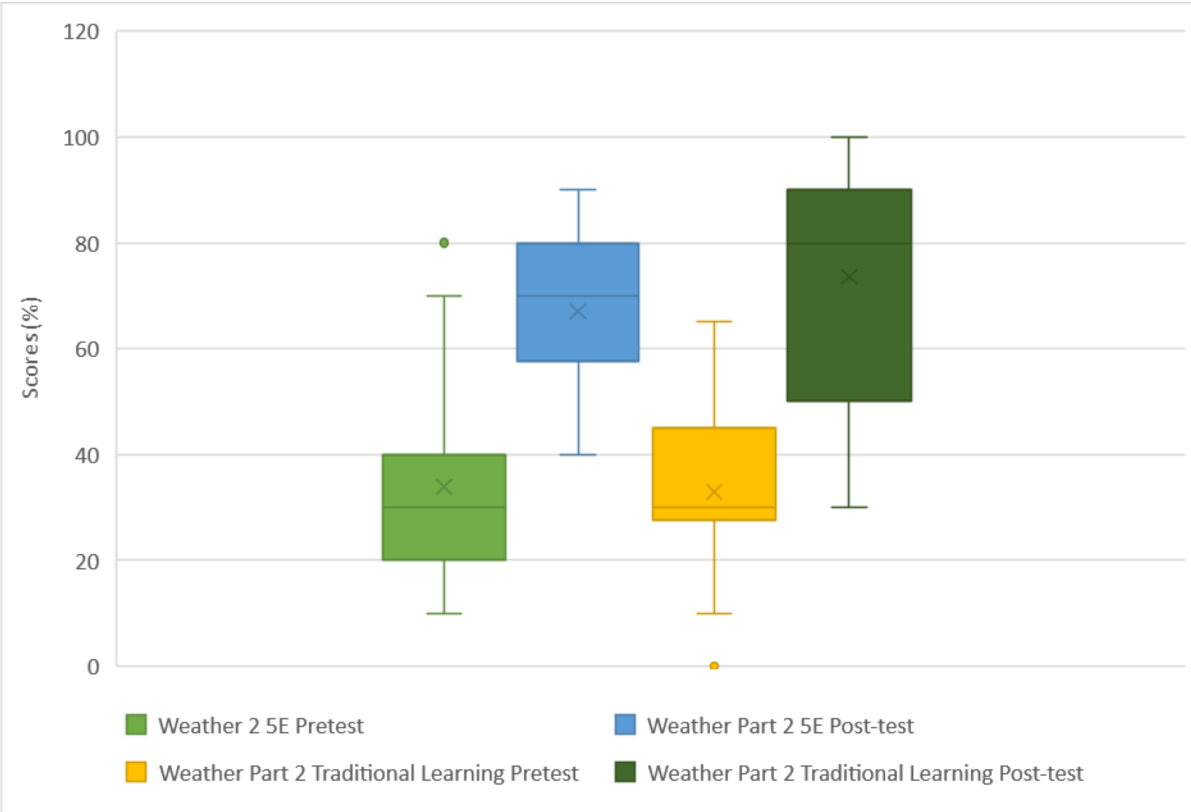

Figure 5. A comparison of the pretest and posttest scores of students who took the Weather Part 2 Test, (*N*=43).

When asked which units students believed they learned the most during eleven out of the twelve students believe they learned more during the 5E units. The reason for why students believed they learned the more during the 5E units was because it was more hands on and it allowed them time to explore the concepts more in depth. One student mentioned that the 5E unit gave them “more time to look over the material and allowed him to work at his own pace” while another student mentioned that it allowed students to “figure things out on their own.” Other students enjoyed the 5E units because they “physically did stuff such as determining the relative ages in rock layers” as opposed to the traditional learning which we did notes that one student said, “went in one ear and out the other.” The one student that preferred the traditional learning method just “preferred to do notes and worksheet” in class.

Delayed Posttest Analysis

A delayed posttest was administered two weeks after the completion of each unit to determine student content knowledge retention. The 5E group obtained an average score of 84% and the range of scores was 73% and half of the students scored between 79% and 93% on the geologic time and fossils delayed posttest. The traditional learning group achieved an average score of 81% with half of the students scoring between 73% and 91% on the geologic time and fossils posttest. The range of scores for the traditional learning group on the geologic time and fossils posttest was 46%. A t-test was completed to find a p-value of 0.54 resulting in a failure to reject the null hypothesis (Figure 6).

On the oceanography delayed posttest, the 5E group earned an average score of 57% with half of the students scoring between 43% and 74% and the range of scores was 64%. The traditional learning group had an average of 67% on the oceanography delayed posttest. The traditional learning group had a higher interquartile range which was between 49% and 93% but it also had a higher difference between the highest and lowest test scores which was 96%. A t-test performed between the scores of the groups resulted in a p-value of 0.22 which causes a failure to reject the null hypothesis.

On the Weather Part 1 delayed posttest the 5E group earned an average score of 81%. Half of the students in the 5E group earned scores between 68% and 95% on this test. The difference between the highest and lowest scores for this group was 55%. The traditional learning group had the larger difference of 70% between the highest and lowest scores. The average score of this group was 70% on this test with the range of 58% and 90% being where half of the students scored on the Weather Part 1 delayed posttest. The null hypothesis failed to be rejected when a t-test returned a p-value of 0.08.

Two weeks following the Weather Part 2 posttest students in the 5E group scored an average of 67% on the Weather Part 2 delayed posttest. The scores of this group had a 60% difference between the highest and lowest scores with 75% of the students earning between 50% and 80%. The traditional learning group had an average score of 77% on this delayed posttest with 75% of the students scoring between 65% and 93%. There was a 70% difference between the highest and lowest scores earned on this delayed posttest for the traditional learning group. A p-value of 0.89 was found during a t-test which leads to a failure to reject the null hypothesis meaning there was no difference between the scores of the 5E group and traditional learning group.

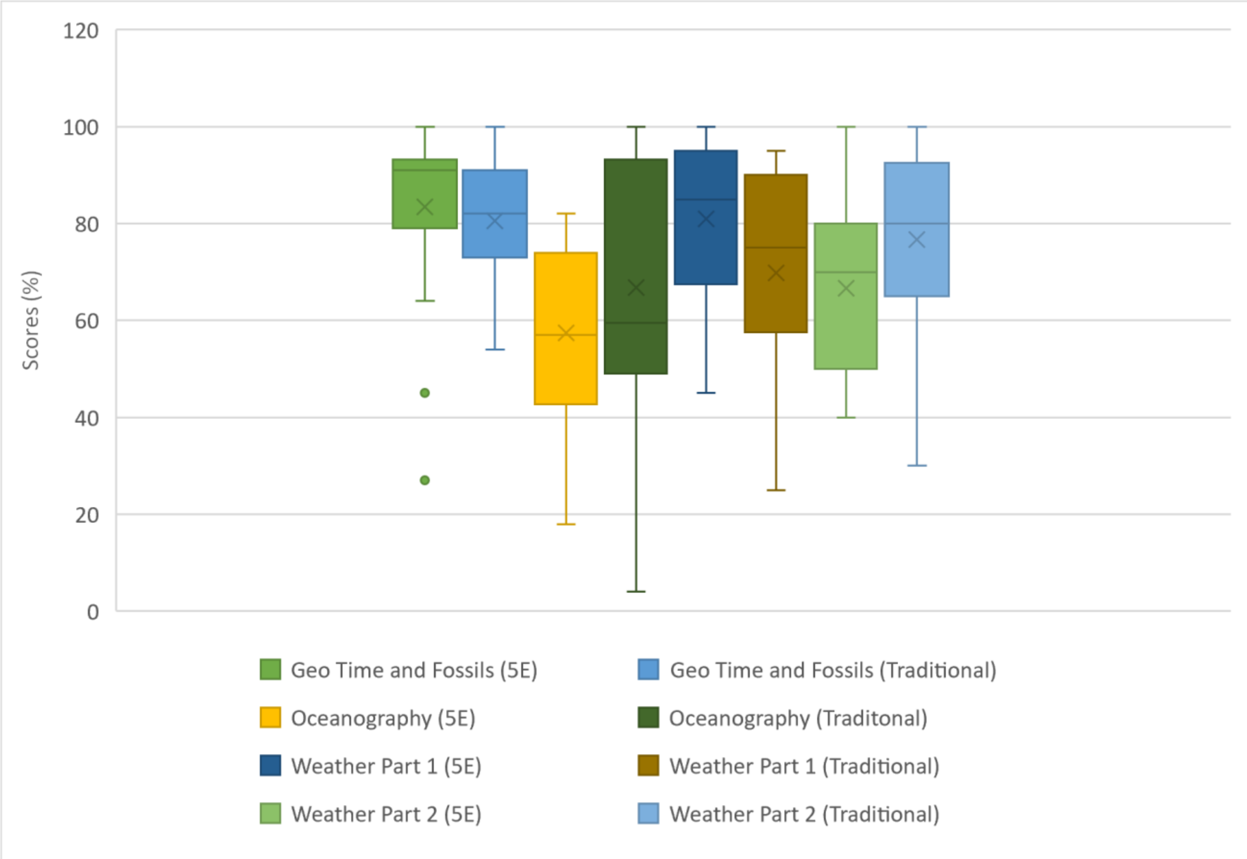

Figure 6. A comparison of student scores on their delayed posttests after learning through the 5E learning cycle or through traditional learning, (Geo Time and Fossils *N*=44, Oceanography *N*=42, Weather Part 1 *N*=42, Weather Part 2 *N*=43).

Next, the delayed posttest scores were compared to the pretest scores for each group during each unit. It was found that there were significant differences between all the pretests and delayed posttests for each unit and group. For example, the 5E group during the geologic time and fossils unit had an increase in most test scores. During the pretest this group of students had 75% of students scoring between 27% and 55% while on the delayed posttest 75% of students scored between 81% and 91%. Another example of this content knowledge retention is from the traditional learning group and the Weather Part 1 unit. On the pretest for this unit the traditional learning students scored an average score of 42% and had an interquartile range between 20%

and 65% while on the delayed posttest the average score increased to 70% and the interquartile range increased to between 60% and 85% (Figure 7).

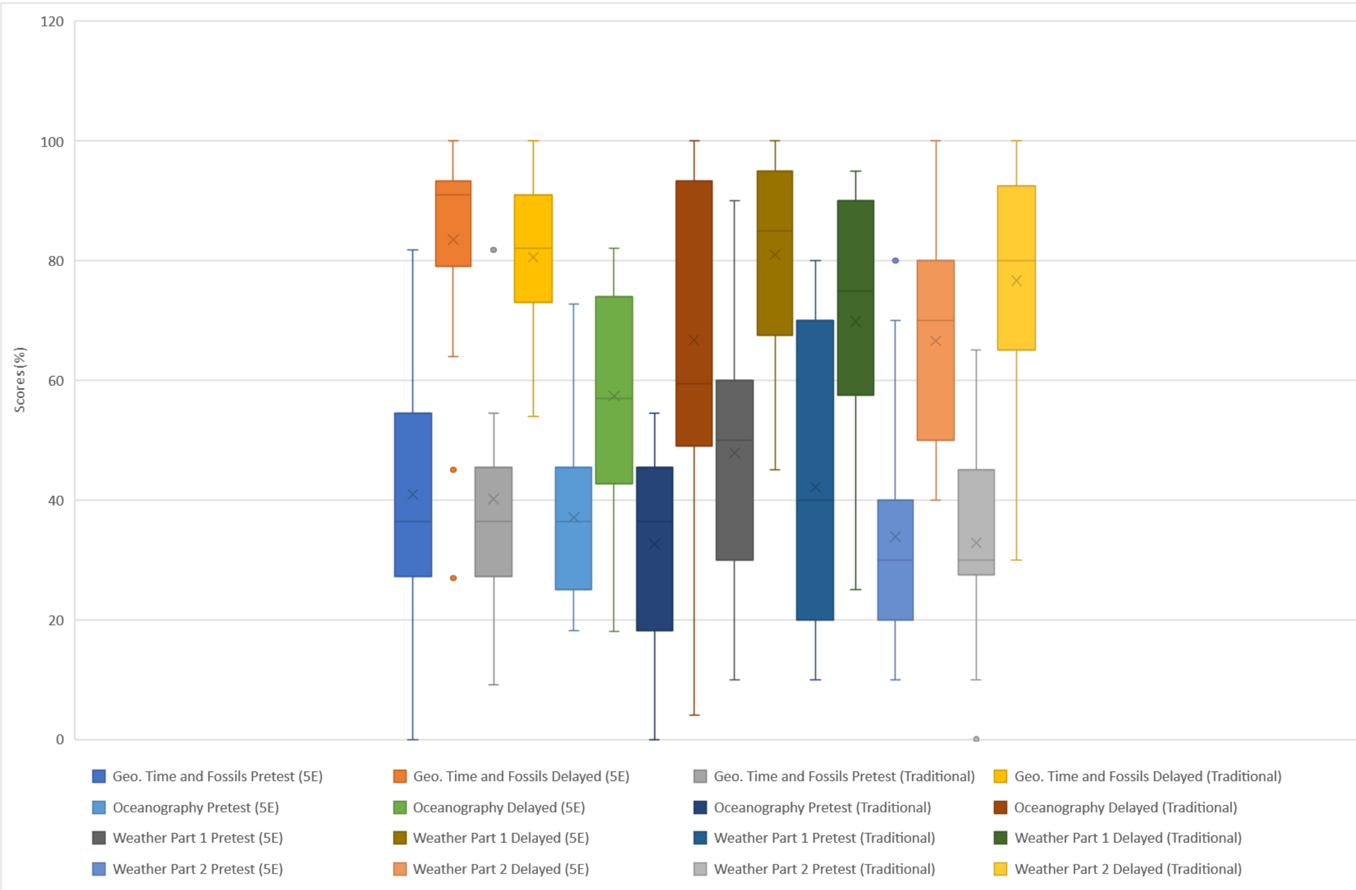

Figure 7. A comparison of the pretest and delayed posttest scores of each unit for both the 5E learning group and the traditional learning group, (Geo Time and Fossils *N*=44, Oceanography *N*=42, Weather Part 1 *N*=42, Weather Part 2 *N*=43).

<u>Engagement Observations</u>

Throughout the study observations of my classes were completed to see the engagement of students during 5E learning and during traditional learning. It was found that 53% of the off-task behaviors took place during 5E units while 47% took place during traditional learning.

Out of all the behaviors observed the one with the highest number of occurrences, 27%, was off task activities on Chromebooks. The next behavior with the highest occurrence rate was talking to peers during instructional time/ directions with 26% of occurrences of off task behavior observed. The least common off task behavior observed was sleeping which only made up 3% of observed behaviors.

Test of Science Related Attitudes (TOSRA)

Before the start of any teaching related to this study students took the Test of Science Related Attitudes (TOSRA) survey. Student responses were at an average of 119.79 out of a total of 210 possible points. The standard deviation for the scores before the completion of a 5E unit was 9.92. The students took the same TOSRA survey after they completed a unit taught with the 5E method. On this survey students got an overall average score of 118.1 points and a had a standard deviation of 13.2 (Figure 8). The two surveys were compared with a paired t-test, and there was a p-value of 0.53 which leads to a failure to reject the null hypothesis.

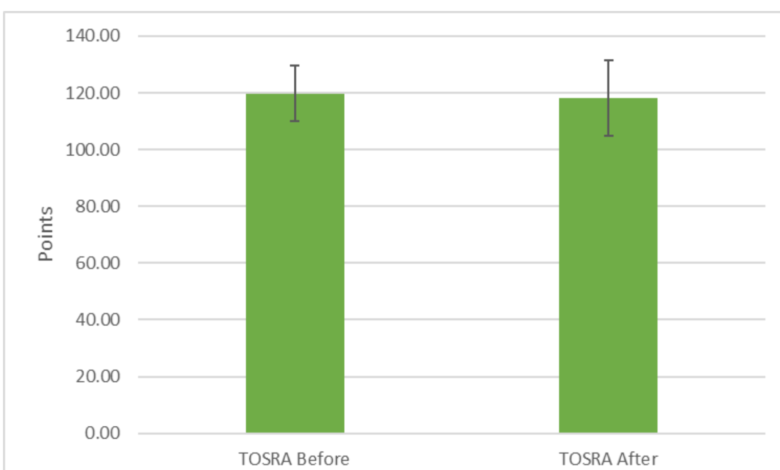

Figure 8. A comparison of the overall scores from the Test of Science Related Attitudes (TOSRA) survey before and after completion of a 5E unit. Error bars represent standard deviation, (*N*=39).

Each of the TOSRA categories (Social Implications, Normality of Scientists, Attitude of Science Inquiry, Adoption of Science Attitudes, Enjoyment of Science Lessons, Leisure Interest in Science, Career Interest in Science) were also compared using paired t-tests once students completed the surveys. The social implications of science had an average score of 21.3 before the completion of the 5E lesson and an average of 21 following the 5E lesson and no significant difference. There was also no significant difference between the scores before and after the 5E lesson for the normality of scientist category which had a before average of 20.8 and after average of 21. The attitude of science inquiry had an increase in averages, as it increased to 22.4 after having an average score of 21.9 before, but there was no significant difference between those scores. Adoption of science attitudes also had a change in average scores since the scores moved from 21.4 to 21.1 but it did not move enough to have a significant difference. The enjoyment of science lessons showed a small increase as it moved up from 18.2 to 19.3 (Figure 9). It was also not enough to be a significant difference. When asked if they enjoy science class the interviewees were split with their answers. Six out of the twelve said that they did enjoy science class and the other six said it depends on the day. The six students who enjoyed science classes mentioned that they enjoyed science because it is “fun and interesting” or that there is “so much you can learn about science” with so many different topics. The students that said it depends on the day if they enjoy science class told me it depends on the topic, activities done in class, and their personal mood. The category related to students’ leisure interest in science did not increase by much. The before average score was 14.3 and the after score was 14.5 which did not result in a significant difference. When asked if they read about, listen to podcasts about, or study science outside of school ten out of the twelve students said that they did. There was a wide variety of ways students learned about science outside of school. One student liked to do "research on different metals to use in jewelry forging" another student "enjoys reading about stars and rocks" while another is "forced to watch science shows with her father."

The only category in which the null hypothesis was rejected was the career interest in science category. This category had a p-value of < 0.0001. Before the completion of a 5E unit the score was 10.6 and after the 5E lesson the average score increase to 15.7 (Figure 9). When asked if they would ever consider a career in science eight of the twelve students said yes. The reason for why students would like to have a career in science was very diverse. One student told me that it was her "childhood dream to become a veterinarian or vet-tech", another student wants to be a paleontologist because he "would like to go out and find fossils for a living." Other students mentioned that any career in science would interest them because they find science fascinating and another student would like a career in science because "some scientists make a lot of money." The students that would not consider a career in science said that a science career would "not hold their interest long enough" or that they already had a job lined up in a family business after they graduate.

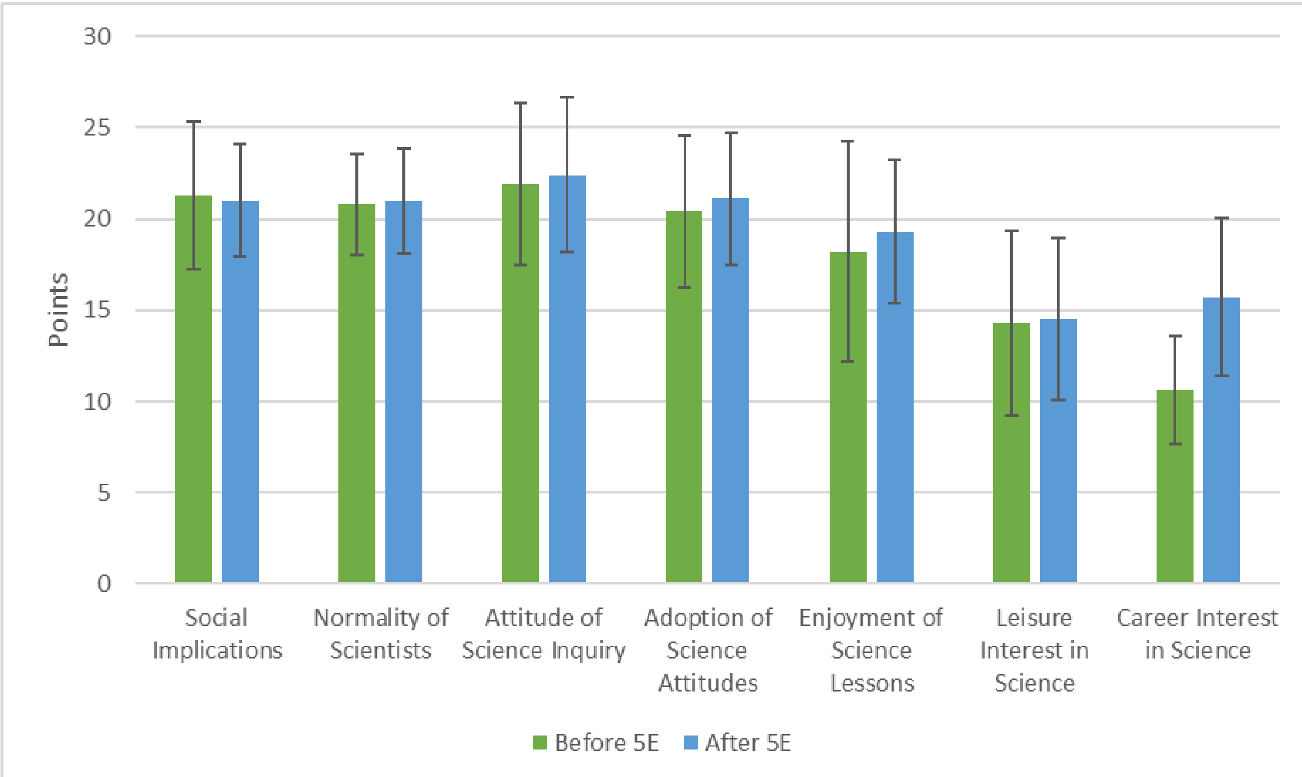

Figure 9. Average scores for each of the TORSA categories from before learning through the 5E learning cycle and after learning through the 5E learning cycle. Error bars represent standard deviation, (*N*=39).

CLAIMS, EVIDENCE, AND REASONING

Through the collection of data in this study it was found that there were several potential effects the 5E learning cycle could have on high school science students. Some of these effects include student learning, content knowledge retention, student engagement, and attitudes toward science.

Effects on Student Learning

This study has shed some light onto the effects of different teaching styles and how they affect students. It was found that both groups of students showed an increase in knowledge after completing each of the units. However, there was no significant difference between the learning of students from the 5E learning group and the traditional learning group. A study by Rissing and Cogan (2009) looked at student learning between two groups of students, one taught with an inquiry-based approach and one with a traditional approach, who were college biology students learning about enzymes. It was found that the inquiry-based approach increased student learning. This is different than my study since I found no differences among approaches. A possible reason for this could have been that my study was on high school students. An interesting study could be to teach several grade levels using the 5E learning method and determine student learning between grade levels.

Effects on Student Content Knowledge Retention

According to this study, teaching style had no effect on student content knowledge retention. However, students were retaining content knowledge in both groups. A similar study on sixth grade science students showed that as the amount of inquiry-based learning increased the amount of content students retained increased. However, it was found in that study that a complete student-centered inquiry approached caused a dip in student learning and content knowledge retention. It is believed that the students in that study lacked enough previous knowledge to effectively handle a unit that was completely student centered (Olsen & Rule, 2017). One possible reason that there was not a difference between the content knowledge retained by students in my study could be that the students lacked the previous knowledge to effectively learn new content during the 5E lessons. Another possible reason could be that the students never fully experienced a total 5E unit before, so they might not have enough experience with 5E lessons to be comfortable with learning in this fashion. An idea for future research could be to spend a few days reviewing content students should have learned in previous science classes, then teach them using the 5E method to determine if it helps students learn and retain knowledge longer. It would also be interesting to administer delayed posttests after a longer time to see how long students retain their knowledge.

Effects on Student Engagement

It was found that the learning style did not affect how engaged students were in their own learning. According to the McCollough Science Engagement Tally Sheet the teaching style also did not affect how engaged students were. According to student interviews this data makes sense. Eight of the twelve students interviewed mentioned that they felt more engaged during the traditional learning units. Students believed they were most engaged during units that they found more interesting and that the teaching style did not matter to them. However, the four students that selected 5E units as the ones they felt most engaged during all mentioned that they liked the

5E lessons because they “could not hide in the corner” and it forced them to “be active and more hands on.”

The highest recorded off-task behavior was off-task Chromebook use. A possible reason for this could be how much Chromebooks were used for research and videos in the classroom and how easily students can be distracted by adds or other noneducational videos. Personally, I get off track while looking things up online and believe the same could have happened to some of these high schoolers. In the traditional learning group, we used Chromebooks for a few activities which did not involve researching or watching videos. One study examined the relationship between smartphone - laptop use during lectures and student engagement. This study found that laptop use during lectures lead to a decreased student engagement during lectures (Witecki & Nonnecke, 2015). A possible next research project could be to see how using Chromebooks during 5E units affected student learning by allowing one group of students to use Chromebooks during 5E teaching and teach another group using the 5E and not allowing students to use Chromebooks.

Effects on Students’ Attitudes Toward Science

According to my study it was found that the 5E learning style had no effect on students’ attitude toward science. All the TOSRA categories except for one was not affected by the 5E teaching style. The only category affected by the 5E learning cycle was student career interest in science. One possible reason that an interest in science careers could have increased could be that students were able to see the hands-on nature of science through an inquiry-based approach. Before my class and the start of this study students mostly experienced a traditional teaching style in which they took lots of notes and were expected to remember them. Very few labs were completed, and students were not given time to research topics that interested them. Once implemented, the 5E teaching method allowed students to experience more science through labs and research projects that interested them. Some of the labs that we completed as part of this study included cleaning up a mock oil spill, collecting weather data (relative humidity and air pressure), and hurricane tracking. Most of these lab activities could be connected to a career in science such as meteorology or environmental scientists. Projects we completed in class also could relate to careers in science. One such project was a project in which students had to write a weather report and record themselves reporting the weather for a three-day period. Another project involved students researching fossils found around the world and in our area. I wonder if these activities showing students some of the careers in science, and how active scientists really are, helped changed the minds of some students about their future career choices. Another study could be completed to see what specifically caused this change in interest in a career in science.

Reflections on Action Research

While reflecting on this research study I have a few things that I believe affected the quality of the study. First, I believe the sample size was too small. For the most part the posttest scores of students from the 5E group were higher than those of the traditional learning group even though they were not statistically significant. It would be interesting to see if a larger student population would produce a statistically significant difference. Another thing that I would like to have done differently is to do a survey for students at the end of the study in place of the student interviews. I believe some of the students were not honest with me since they were speaking to me face-to-face. For example, none of the students told me that they did not like science class even though you can tell that they do not care for science by the way they act in class. I believe that an anonymous survey would have been a better option for this because students could express their thoughts more openly.

Impact of Study on Author

As an educator this study was very helpful. As a result of preparing for and implementing this study I learned so much about the 5E learning cycle, my students, and tracking learning. Before becoming a member of the MSSE program the only way I knew how to teach was the traditional method of notes and worksheets. Now I enjoy using the 5E method to teach students because it challenges them and forces them to think. The 5E teaching style also changes things up in class. I do believe that the traditional teaching method has a place in the classroom but needs to be broken up with the 5E learning cycle to change things up. To further mix things up I am actively searching for interesting new ways to teach. I greatly enjoyed working with students in this study and learning about them. Interviewing students allowed me to learn more about their future career choices and what types of activities they enjoyed doing. This builds a rapport with the twelve students that I interviewed that has created a welcoming classroom environment. I have also noticed that the students that I interviewed are more willing to chat with me before and after class since they feel more comfortable around me. I also enjoyed having a way to visualize student learning. Previously, I completed my student performance measure (SPM) each year by filling in an Excel file with student test scores and then calculate the differences in their test scores. I noticed most scores went up between the pretests and posttests that I administered but never analyzed it to see if there was a significant difference. It was nice to have assurance that students are learning throughout the duration of this study. It was also interesting to see how students were able to retain the information for a few weeks after the completion of the study. I plan to continue tracking student learning in this way as I move forward in my career to monitor my own teaching and to ensure students are learning.

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APPENDICES

APPENDIX A

INSTITUTIONAL REVIEW BOARD EXEMPTION

MONTANA STATE UNIVERSITY
Request for Designation of Research as Exempt
MSSE Research Projects Only
(6/16/14)

****

THIS AREA IS FOR INSTITUTIONAL REVIEW BOARD USE ONLY. DO NOT WRITE IN THIS AREA.
Confirmation Date: 12/1/21 Mark T. Quinn
Application Number:

****

DATE of SUBMISSION: 11/21/21

-Okay as exempt
-MSSE classroom assessment
-Little/no risk
-Principal approved
-No concerns
MQ 12/1/21

Address each section – do not leave any section blank.

I. INVESTIGATOR:

Name: **David McCollough**
Home or School Mailing Address: **124 Russell Rd. Fenelton, PA 16034**
Telephone Number: **724-504-1038**
E-Mail Address: **mccodf22@gmail.com**
DATE TRAINING COMPLETED: **February 19, 2021** *[Required training: CITI training; see website for link]*

Investigator Signature David McCollough

Name of Project Advisor: **Dr. Carl Graves**
E-Mail Address of Project Advisor: carl.graves@ecat1.montana.edu

II. TITLE OF RESEARCH PROJECT: **Effects of the 5E Learning Cycle on High School Science Students**

III. BRIEF DESCRIPTION OF RESEARCH METHODS (If using a survey/questionnaire, provide a copy).

To examine how the 5E learning cycle affects students two equally sized groups of students will be formed. Each group will take the same pretest before any learning takes place. One group of students will be taught a unit using the 5E learning cycle while the other group will learn using traditional instructional methods (lectures and book readings). Following the unit both groups will take an identical post-test to determine student growth. Two weeks after completing the unit each group will take an identical delayed post-test to determine student content knowledge retention. This process will be completed for four total units and the treatment the student groups receive will be switched after each unit.

Before any instruction begins on the units examined in this study students will complete the Test of Science Related Attitudes (TORSA) Survey. Students will then complete the TORSA survey once again after they complete one unit that is taught using the 5E learning cycle (Appendix B).

While being taught, each group of students will be observed by administrators or colleagues. Those observing will be looking for off-task behaviors and marking them on the McCollough Science Engagement Tally Sheet. Each group of students will be observed two times during their 5E lesson and two times during their traditional lessons. The number of times students engage in off task behaviors will be compared between the 5E lessons and traditional lessons (Appendix C).

Following the completion of the study six student (two high achieving, 2 middle achieving, and 2 low achieving students) from each group will be interviewed. The questions asked to the students are found on the McCollough 5E Science Interview Questions Sheet (Appendix D).

APPENDIX B

GEOLOGIC TIME PRETEST/ POSTTEST/ DELAYED POSTTEST

Geologic Time Pretest/Posttest/ Delayed Posttest

Name:

Read each question carefully, and then select the correct answer.

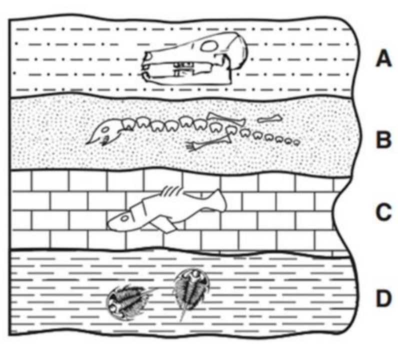
Dinosaurs, small mammals, and birds are found in this time period?

A.) Cenozoic
B.) Mesozoic
C.) Paleozoic
D.) Precambrian

In which time period are we currently living?

A.) Precambrian
B.) Paleozoic
C.) Mesozoic
D.) Cenozoic

Use the diagram to answer this question. Which rock layer is the newest?



A.) A
B.) B
C.) C
D.) D

Saying you are younger than your brother is an example of ___________________.

A.) Absolute Age
B.) Relative Age

C.) Exact Age

D.) Fossilization Age

Which type of fossilization results when the whole animal is preserved?

A.) Mold

B.) Ice/ Freezing

C.) Replacement

D.) Carbonization

Special fossils that show geologist the boundaries of geologic time are called _______________.

A.) Index Fossils

B.) Trace Fossils

C.) Mold Fossils

D.) Cast Fossils

Which type of rock are fossils most commonly found in?

A.) Igneous

B.) Sedimentary

C.) Metamorphic

D.) Granite

Which of the following is an example of a trace fossil?

A.) Footprints

B.) Skull

C.) Shell

D.) Plant Leaf

Which type of rock and fossil dating gives the exact age of a rock or fossil?

A.) Relative Dating

B.) Differential Dating

C.) Geologic Time Dating

D.) Absolute Dating

Write a short paragraph in response to each of the following question.

How do fossils support the theory of Continental Drift?

APPENDIX C

OCEANOGRAPHY PRETEST/ POSTTEST/ DELAYED POSTTEST

Oceanography Pretest/Posttest/ Delayed Posttest

Name:

Read each question carefully, and then select the correct answer.

Surface ocean currents are driven mostly by ________________.

A.) Temperature differences

B.) Hurricanes

C.) Wind

D.) Density differences

Circulating air is deflected towards the right in the northern hemisphere and left in the southern hemisphere because of ____________________.

A.) The rotation of the Earth

B.) Strong deep ocean currents

C.) Density differences

D.) Absorption of the sun's energy

Oceanic crust is different from continental crust because it is ______________________.

A.) Older

B.) Less dense

C.) Thicker

D.) A different chemical composition

Which elements (besides hydrogen and oxygen) are most abundant in the oceans?

A.) Sodium and Chlorine

B.) Magnesium and Chlorine

C.) Sodium and Sulfur

D.) Sulfur and Calcium

Where does the energy come from to heat the ocean?

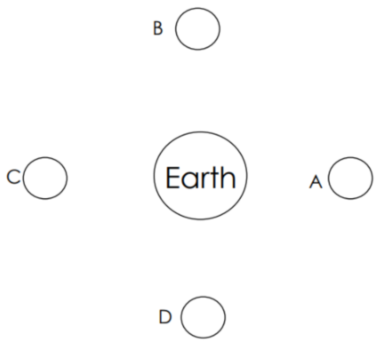
A.) Hydrothermal vents

B.) The magma in the Earth

C.) The sun

D.) Heat produced by organisms living in the oceans

Use the picture below. In which position(s) would the Earth experience a spring tide? (select all that apply)



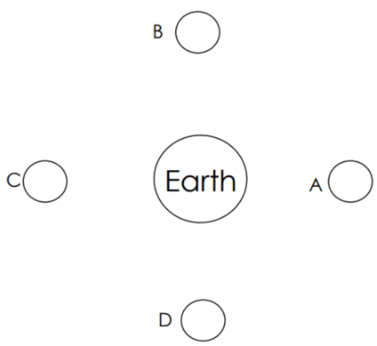
A.) A

B.) B

C.) C

D.) D

Use the picture below. In which position(s) would the Earth experience a neap tide? (select all that apply)?



A.) A

B.) B

C.) C

D.) D

What is the relationship between density and salinity?

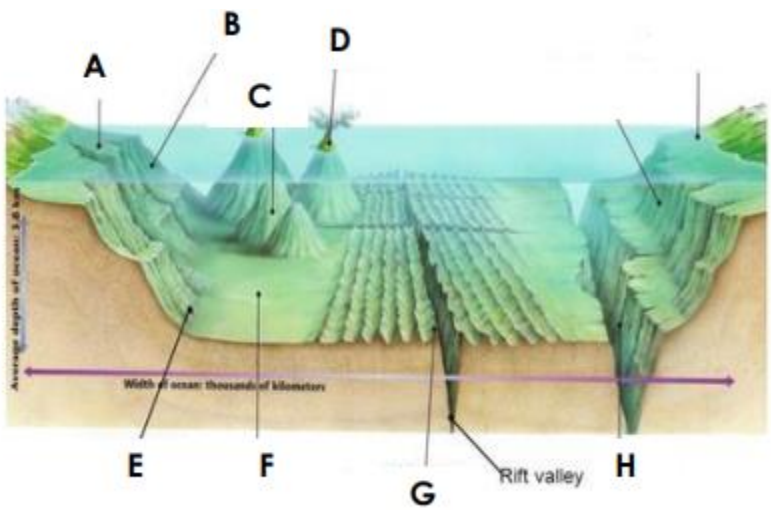
A.) There is no relationship between the density and salinity.

B.) When water has more salt the water is more dense.

C.) When the water has more salt the water is less dense.

D.) When the water has less salt the water is more dense.

Use the image below. What sea floor feature is labeled E in the image below?



A.) Continental Shelf
B.) Continental Slope
C.) Sea Mount
D.) Continental Rise

Write a short paragraph in response to each of the following question.

What role does gravity play with the ocean tides? Be specific.

APPENDIX D

WEATHER PART 1 PRETEST/ POSTTEST/ DELAYED POSTTEST

Weather Part 1 Pretest/Posttest/ Delayed Posttest

Name:

Read each question carefully, and then select the correct answer.

The bottom layer of the atmosphere is which we live is called the ________________.

A.) Mesosphere
B.) Stratosphere
C.) Thermosphere
D.) Troposphere

This layer of the atmosphere contains ozone that filters UV radiation.

A.) Mesosphere
B.) Stratosphere
C.) Thermosphere
D.) Troposphere

On a map showing temperature distributions, what are the lines connecting points of equal temperature?

A.) Isobars
B.) Isotemps
C.) Isotherms
D.) Equigrads

Which gas is most abundant in clean, dry air?

A.) Argon
B.) Carbon dioxide
C.) Nitrogen
D.) Oxygen

What is the general term for water vapor in the air?

A.) Capacity
B.) Condensation
C.) Humidity
D.) Saturation

Compared to clouds, fogs are…

A.) A different composition

B.) At lower altitudes

C.) Colder

D.) thicker

The ratio of air's actual water-vapor content to the amount of water needed for saturation is the _______________.

A.) Adiabatic Rate

B.) Dew Point

C.) Relative Humidity

D.) Water Capacity

Which of the following clouds are high, white, and thin?

A.) Cirrus

B.) Cumulus

C.) Nimbostratus

D.) Stratus

Which of the following forms when supercooled raindrops freeze on contact with solid objects near Earth's surface?

A.) Freezing rain

B.) Hail

C.) Sleet

D.) Snow

Write a short paragraph in response to each of the following question.

As you drink an ice-cold beverage on a hot day, the outside of the glass becomes wet. Explain why this happens. Be specific.

APPENDIX E

WEATHER PART 2 PRETEST/ POSTTEST/ DELAYED POSTTEST

Weather Part 2 Pretest/Posttest/ Delayed Posttest

Name:

Read each question carefully, and then select the correct answer.

Variations in air pressure from place to place are the principal cause of ______________.

A.) Clouds
B.) Lows
C.) Hail
D.) Wind

What is the pressure zone associated with rising air near the equator?

A.) Equatorial low
B.) Equatorial high
C.) Subtropical low
D.) Subtropical high

In what stormy region do the westerlies and polar easterlies converge?

A.) Equatorial low
B.) Subpolar high
C.) Polar front
D.) Subtropical front

What device is used to measure air pressure?

A.) Barometer
B.) Thermometer
C.) Anemometer
D.) Psychrometer

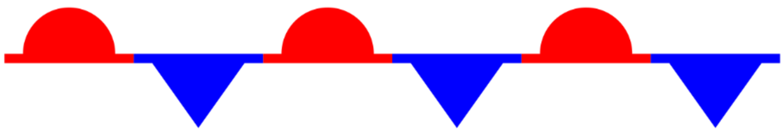
What weather event causes unusually warm waters off the Pacific coast of South America?

A.) La Niña
B.) Cyclone
C.) El Niño
D.) Isobar

Which of the following best describes weather near the center of a region of high pressure?

A.) Cloudy and rain
B.) Clear and fair
C.) Hurricane
D.) Fog

What does this symbol represent on a weather map?

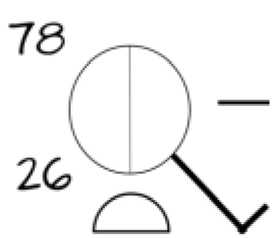


A.) Cold Front
B.) Warm Front
C.) Occluded Front
D.) Stationary Front

What happens at an occluded front?

A.) A slow-moving warm air mass pushes a cold moving air mass out of the way.
B.) A fast-moving warm air mass pushes a fast-moving cold air mass out of the way.
C.) A warm air mass is trapped between two cold masses.
D.) A warm and cold air mass meet and are unable to move each other out of the way.

What is the temperature at this weather station?



A.) 78
B.) Not available
C.) 26
D.) 104

Write a short paragraph in response to each of the following question.

If you are looking for a location to place a wind turbine to generate electricity, how would you use the spacing of isobars in making your decision?

APPENDIX F

MCCOLLOUGH SCIENCE ENGAGEMENT TALLY SHEET

McCollough Science Engagement Tally Sheet

Participation in this research is voluntary, and participation or non-participation will not affect a student's grades or class standing in any way.

Off Task Behavior	Occurrences
Playing with objects	
Calling Out	
Talking to Peers During Instructional Time/ Directions	
Noise Making	
Sleeping/ Head Down	
Cell Phone Use	
Off task Activity on Chromebooks (YouTube, work for other classes, shopping, games)	
Redirection by teacher	

APPENDIX G

TEST OF SCIENCE RELATED ATTITUDES (TORSA) SURVEY

TORSA Survey

Participation in this research is voluntary, and participation or non-participation will not affect a student's grades or class standing in any way. Please select the response that most closely reflects your thoughts on each prompt. (SA = strongly agree, A = agree, N = neutral, D = disagree, SD = strongly disagree)

Question					
1.) Money spent on science is well worth spending.	SA	A	N	D	SD
2.) Scientists usually like to go to their laboratories when they have a day off.	SA	A	N	D	SD
3.) I would prefer to find out why something happens by doing an experiment than by being told.	SA	A	N	D	SD
4.) I enjoy reading about things which disagree with my previous ideas.	SA	A	N	D	SD
5.) Science lessons are fun.	SA	A	N	D	SD
6.) I would like to belong to a science club	SA	A	N	D	SD
7.) I would dislike being a scientist after I leave school.	SA	A	N	D	SD
8.) Science is man's worst enemy.	SA	A	N	D	SD
9.) Scientists are about as fit and healthy as other people.	SA	A	N	D	SD
10.) Doing experiments is not as good as finding out information from teachers.	SA	A	N	D	SD
11.) I dislike repeating experiments to check that I get the same results	SA	A	N	D	SD
12.) I dislike science lessons.	SA	A	N	D	SD
13.) I get bored when watching science programs on TV at home.	SA	A	N	D	SD
14.) When I leave school, I would like to work with people who make discoveries in science.	SA	A	N	D	SD
15.) Public money spent on science in the last few years has been used wisely.	SA	A	N	D	SD
16.) Scientists do not have enough time to spend with their families.	SA	A	N	D	SD
17.) I would prefer to do experiments than to read about them.	SA	A	N	D	SD
18.) I am curious about the world in which we live.	SA	A	N	D	SD
19.) School should have more science lessons each week.	SA	A	N	D	SD
20.) I would like to be given a science book or piece of scientific equipment as a present.	SA	A	N	D	SD
21.) I would dislike a job in a science laboratory after I leave school.	SA	A	N	D	SD
22.) Scientific discoveries are doing more harm than good.	SA	A	N	D	SD
23.) Scientists like sports as much as other people do.	SA	A	N	D	SD
24.) I would rather agree with other people than do an experiment to find out for myself.	SA	A	N	D	SD
25.) Finding out about new things is unimportant.	SA	A	N	D	SD
26.) Science lessons bore me.	SA	A	N	D	SD
27.) I dislike reading books about science during my holidays.	SA	A	N	D	SD

28.) Working in a science laboratory would be an interesting way to earn a living.	SA	A	N	D	SD
29.) The government should spend more money on scientific research.	SA	A	N	D	SD
30.) Scientists are less friendly than other people.	SA	A	N	D	SD
31.) I would prefer to do my own experiments than to find out information from a teacher.	SA	A	N	D	SD
32.) I like to listen to people whose opinions are different from mine.	SA	A	N	D	SD
33.) Science is one of the most interesting school subjects.	SA	A	N	D	SD
34.) I would like to do science experiments at home.	SA	A	N	D	SD
35.) A career in science would be dull and boring.	SA	A	N	D	SD
36.) Too many laboratories are being built at the expense of the rest of education.	SA	A	N	D	SD
37.) Scientists can have a normal family life.	SA	A	N	D	SD
38.) I would rather find out about things by asking an expert than by doing an experiment.	SA	A	N	D	SD
39.) I find it boring to hear about new ideas.	SA	A	N	D	SD
40.) Science lessons are a waste of time.	SA	A	N	D	SD
41.) Talking to friends about science after school would be boring.	SA	A	N	D	SD
42.) I would like to teach science when I leave school.	SA	A	N	D	SD

APPENDIX H

MCCOLLOUGH SCIENCE 5E INTERVIEW QUESTIONS

McCollough Science 5E Interview Questions

These questions will administered near the end of the research project once both groups have completed two 5E units and 2 traditional units. Participation in this research is voluntary, and participation or non-participation will not affect a student's grades or class standing in any way.

1.) Which unit was your favorite (Geologic Time, Oceanography, or Meteorology)? Why?
2.) What was your favorite part about the geologic time/ oceanography/ meteorology unit? Why?
3.) Which teaching style did you prefer the traditional or 5E learning cycle? Why?
4.) Why did you dislike the other teaching style?
5.) Which teaching style do you believe you learned the most during? Why?
6.) During which units do you believe you were most engaged during science class? Why?
7.) During which units do you believe you were least engaged during science class? Why?
8.) Do you enjoy science class? Why or why not?
9.) Do you read about, listen to podcasts about, or study science outside of school?
10.) Would you ever consider a career in science? Why or why not?
11.) Anything else you would like me to know?