DOES TEACHING SCIENTIFIC INQUIRY THROUGH THE 5E LEARNING CYCLE
AFFECT NINTH GRADE EARTH SCIENCE STUDENTS’ ENGAGEMENT
AND CONCEPTUAL UNDERSTANDING?

by

Tyler Hollow

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

of

Master of Science

in

Science Education

Montana State University
Bozeman, Montana

July 2018
©COPYRIGHT

by

Tyler Hollow

2018

All Rights Reserved
ACKNOWLEDGMENTS

I would like to thank the people that helped me in the process of writing my Action Research. I would like to thank my wife Mary for helping me manage my time for this project and her moral support. I would like to thank my daughter Elsie and my son Cooper for their patience with my time away. I would like to thank my Science Reader Dr. Andrew Jakes for his science research perspective on this paper. I would like to thank Dan Hollow and Lindsay Hall for editing this paper. And, I would like to thank my advisor Walt Woolbaugh for guiding me through the Action Research process.
# TABLE OF CONTENTS

1. INTRODUCTION AND BACKGROUND ................................................................. 1

2. CONCEPTUAL FRAMEWORK ............................................................................ 4

3. METHODOLOGY .............................................................................................. 9

4. DATA AND ANALYSIS .................................................................................. 19

5. INTERPRETATION AND CONCLUSION .......................................................... 45

6. VALUE .......................................................................................................... 52

7. REFERENCES CITED .................................................................................... 56

8. APPENDICES ................................................................................................ 59

| APPENDIX A | Montana State University Institutional Review Board Exemption of Review | 60 |
| APPENDIX B | Administrative Approval and Exemption Regarding Informed Consent | 62 |
| APPENDIX C | Treatment Unit and Non-Treatment Unit Curriculum | 64 |
| APPENDIX D | Student Science Inquiry Survey | 69 |
| APPENDIX E | Student Interview Questions | 71 |
| APPENDIX F | Student Questionnaire | 73 |
| APPENDIX G | Responses to Student Interview Questions | 76 |
| APPENDIX H | Teacher Journal Reflections | 80 |
LIST OF TABLES

1. Comparison of Instructional Strategies of Scientific Inquiry and Traditional ..........12
2. Research Triangulation Matrix of Instruments Used to Collect Data on AR ..........16
3. Comparison of Pre- and Post-Summative Assessments and Normalized Gains for Treatment and Non-Treatment Units, (N=44) .................................................................21
4. The Student Science Inquiry Survey Percentage of Students’ Level of Confidence During Pre-, Mid-, and Post-Assessment, (N=44) .................................................................44
LIST OF FIGURES

1. The Action Research Data Collection Instruments Used for the Treatment and Non-Treatment Units .......................................................... 11
2. Comparison of Non-Treatment Unit and Treatment Unit Concept Map Scores,........ 22
3. Pre- and Post-Assessments of the Misconception Probe “Is it a Theory?” ............ 24
4. Pre- and Post-Assessments of the Misconception Probe “What Happens to Stars When they Die?” ......................................................... 25
5. Student Questionnaire Responses for Pre- and Post-Assessment for Teaching Methods)....................................................................................... 28
6. Student Questionnaire Responses for Pre- and Post-Assessment for Engagement, .. 29
7. Teacher Journal Reflections Comparing Traditional Instruction to Science Inquiry Instruction.......................................................................................... 35
8. Student Questionnaire Responses for Attitude for Pre- and Post-Assessment of Treatment Unit ................................................................. 38
9. Pre- and Post-Assessment Results of Science Inquiry Lab .................................. 42
10. Comparison of Pre- and Post-Assessment Science Inquiry Lab ............................. 42
11. Science Inquiry Lab Evaluation Components for Post-Assessment ....................... 45
ABSTRACT

I teach ninth grade earth science at Helena High School in Helena, Montana. I conducted Action Research (AR) in two of my class periods (51 students). Most of my students are Caucasian and 19.6% utilize Special Education Services. The purpose of this AR was to assess the effects of scientific inquiry on students’ conceptual learning and engagement, and effects this might have on the teacher. Scientific inquiry has been defined by Next Generation Science Standards Science and Engineering Practices, which our district has recently adopted. The long-term goal for this AR is to increase success for ninth grade students by engaging them in their learning, teaching them the process of science and increasing their understanding of the natural world through scientific inquiry instruction. The AR essential question is, “How does teaching scientific inquiry through the 5E Learning Cycle and other strategies affect ninth grade earth science students’ engagement and their conceptual understanding?” For the methodology, I compared a treatment unit, taught through scientific inquiry teaching strategies, with a non-treatment unit, taught through traditional teaching strategies. The findings from the AR demonstrate that students had an increase in conceptual understanding in the scientific inquiry taught unit and improved student science inquiry skills. Results showed that similar student engagement occurs in activities that are taught in science inquiry instruction and traditional instruction. Students demonstrated positive attitudes during both units of study when the lessons were engaging. Students were highly engaged in lessons when they were hands-on, phenomenon were demonstrated, presentations were interesting, and when they were working on projects. I plan on using many teaching strategies from this AR, such as creating one 5E Learning Cycle for each unit, increasing the number of projects that are student driven, and include more demonstrations during presentations to increase students’ understanding.
INTRODUCTION AND BACKGROUND

The Action Research (AR) topic is the effects of scientific inquiry on my earth science students and the effect on me as the teacher. For the purposes of this project, AR is an investigation on how a teaching strategy affects an individual’s classroom.

Scientific inquiry is the active engagement of students in asking questions and the process of finding the answer through critical thinking and imagination (Llewellyn, 2013; National Resource Council, 2012). I am very interested in the process of science. I believe that the public has been misguided in their negative critique of scientists in the debate on climate change and vaccinations. I feel that people are negative towards science because they do not understand the process. Therefore, I want to do a respectable job of teaching students the process of science, so they can make informed decisions as voting adults. Additionally, I believe that students need to be engaged in science, enjoy science and understand important concepts to further their learning. For this project I believe engagement in students is asking questions, actively listening, and participating with the desire to learn. The main goal of this research is to teach scientific inquiry and investigate if an improved level of student engagement and conceptual understanding can be obtained through this instructional strategy.

I work in the Helena School District, which has adopted similar standards as the Next Generation Science Standards (NGSS), the main difference being that Montana has added Indian Education for All standards. NGSS were created by a 41-member team working in cooperation with 26 states for two years with the goal of preparing students for college, career and citizenship (Next Generation Science Standards, 2013). NGSS is
composed of three domains. The first domain is Science and Engineering Practices. The second domain is Cross-Cutting Concepts. The third domain is Content. For this research, I have given special attention to the domain of Science and Engineering Practices. These practices are the modern definition of science inquiry (Llewellyn, 2013). The eight practices are: 1. Asking Questions and Defining Problems; 2. Developing and Using Models; 3. Planning and Carrying Out Investigations; 4. Analyzing and Interpreting Data; 5. Using Mathematics and computational Thinking; 6. Constructing Explanation and Designing Solutions; 7. Engaging in Argument from Evidence; and 8. Obtaining, Evaluating and Communicating Information. I have used scientific inquiry teaching strategies discussed in the methodology section to meet the modern definition. Through this research, I hope to find out if science inquiry benefits students’ engagement and performance in school.

The high school where I teach has an 83% graduation rate and studies show that the students’ ninth grade year is an important year for graduation (Sawchuk, 2017), and I believe that increasing student engagement will benefit graduation rates. I plan to share my findings with science teaching colleagues, my students and my administration. My hope is that science inquiry engages students and improves their performance, which may lead to a decrease in the ninth grade failing rate and make this AR a worthwhile investment.

**Purpose**

The purpose of this AR was to assess the effects of scientific inquiry on students’ conceptual learning and engagement, and effects on the teacher. The long-term goal for
this investigation was to increase success for ninth grade students by engaging them in their learning, teaching them the process of science and increasing their understanding of the natural world through science inquiry instruction.

Research Questions

The AR’s essential question: “How does teaching scientific inquiry through the 5E Learning Cycle and other strategies affect 9th grade earth science students’ engagement and their conceptual understanding?” The three sub-questions are: “1. In what ways, does teaching science inquiry impact me as a teacher?” 2. “What student attitudes are present during science inquiry lessons?” and 3. “How are student’s science inquiry skills affected by this treatment?”

Support Team

My support team consists of three individuals: Claire Pichette, Rodney Benson and Andrew Jakes. Claire is a colleague at Helena High School and concurrently enrolled in the MSSE program. Similarly, she is researching the effects of inquiry-based learning, though her attention is on the NGSS Science and Engineering Practice Engaging in Argument. I discussed our treatments and reviewed our results during this year with Claire. Claire critiqued my paper and I reviewed her paper. Rodney is an earth science teacher at Helena High School and has taught for 30 years. I have taught with Rodney for eight years at Helena High School and work closely with him in our earth science Professional Learning Communities. I discussed my treatment, data collection and student reflections with Rod. Rod is a graduate of the MSSE program. Andrew was my Science Reader. Andrew has a PhD from the University of Calgary, where he
completed his dissertation on pronghorn migration. Andrew is currently working for the National Wildlife Federation and as an affiliate to University of Montana. Andrew has presented his research to my class.

CONCEPTUAL FRAMEWORK

The conversation of science inquiry starts with constructivism, which is the theory that students make meaning of the world through their current knowledge and experiences. Additional information is taken in and processed when the learners develop conceptions of their world as they see it. Students come in to class with possible misconceptions that greatly affect their learning (Llewellyn, 2013). John Dewey (1859-1952) was an early constructivist and believed that students learned from a personal interaction of the environment. Dewey knew the importance of student-guided inquiry, where students are investigating their testable questions and researching what they want to know.

The 5E Learning Cycle, which is one of the planned treatments for teaching the scientific inquiry unit, is based on the constructivism theory developed by Dewey. The 5E stand’s for Engage, Explore, Explain, Elaborate and Evaluate, and is a method for delivering science inquiry lessons. During the Engagement phase, the teacher evokes interest through showing students a phenomenon, which is a demonstration exploring the natural world that students try to understand. Misconceptions from students are also gathered in the Engagement phase. Explore is the hands-on work of conducting experiments. During the Elaborate stage, the teacher helps students make connections to content and the real world through direct instruction. Finally, the Evaluation stage is
when teachers ask higher-level questions and get students to reflect on their work or assess student work through rubrics (Llewellyn, 2013).

As mentioned above, I used the 5E Learning Cycle as a science inquiry teaching strategy because of the research supporting this method. Anthony V. Defina (2017) wrote how he uses the 5E Learning Cycle to teach about evolution and the Galapagos Islands. Using evolution as the content piece for the learning objectives, they were able to ask questions, analyze and interpret data, engage in argument from evidence, and obtain, evaluate and communicate information based on the content. In the Engagement phase, pictures were passed around of species and a discussion started on the features, location, wildlife and scientific significance of the islands. Students then researched through films, magazines and other articles to explore plausible explanations for endemic species. In the Exploration phase, groups presented their findings and the teacher presented necessary content. With more information, students were then asked to elaborate on three species with a more focused lens and once again report out. Finally, in the Evaluation phase, students wrote an essay using research skills, learned vocabulary and concepts, and wrote self-reflections on their learning. This article illustrates the application in ninth or tenth grade of the 5E Learning Cycle. I used the strategies from this article to broaden my approach to teaching science inquiry.

The current trend in Science Education is adopting the NGSS. National Resource Council (2012) lays out the groundwork for these standards with supported literature and the standards. National Resource Council are 18 individuals that are well-known for their science background and developed the framework for the Next Generation Science
Standards. Llewellyn (2012) suggests that the NGSS Practices are the same as the skill of science inquiry. The council’s overarching goal is focused on preparing students for college, career and citizenship. The goal stated:

By the end of the 12th grade, all students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussion on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including careers in science, engineering and technology (National Resource Council, 2012, p. 1).

The lens for thinking about this AR can be traced back to work done by the National Resource Council (2005) which reviewed considerable literature and examined a different approach to traditional instruction. The end goal of this work is to help students learn what scientists know, such as concepts, theories and models, and how scientists go about answering questions. Students bring to the classroom outside misconceptions that allow them to function within the content area, but these preconceived misconceptions do not allow them to learn the correct theory, concept or model. Teachers need to unmask the misconceptions, so they can be addressed and the appropriate information can be retained. Moreover, students need to understand what “doing Science” is. Science is about being imaginative, having the ability to reason and experiment, and to observe phenomenon. Students should be guided to research questions that they want to know, to be imaginative in asking questions and to develop a hypothesis. Traditional instruction in a lab with a set of specific steps does not necessarily embody these skills. Students can learn components of what “doing Science” is, but the big picture is not always present in this type of instruction. Students need to reflect on their learning, such as keeping journals on their
understanding of learning targets or their comprehension of complex texts. Reflections should also be made on new questions students have about scientific phenomenon, and how they feel they contribute to group collaboration in scientific inquiry.

Research demonstrates that scientific inquiry can affect engagement and conceptual understanding. One piece of literature reviewed 138 studies on teaching practices “Inquiry-Based Science Instruction—What Is It and Does It Matter? Results from a research Synthesis Years 1984 to 2002 (Miner, Levy, & Century, 2009) addresses the question “What is the impact of inquiry science instruction on K-12 student outcomes?” Within the 138 studies, researchers found 51 studies that showed positive improvement in students’ learning content, while only 2% showed a negative impact. Additionally, the studies showed that students were more likely to have a higher level of understanding of science concepts through science inquiry, though not statistically significantly different. However, when comparing 42 similar studies, they found that higher amounts of inquiry were significantly different when compared to studies with lower amounts of inquiry. Furthermore, and relative to this paper’s AR essential question, the review examined 6 studies that assessed engagement. Interestingly, five of these studies showed greater student engagement through assessing learning concepts, though this study did not show an overwhelming trend for student learning through science inquiry. The main take-aways were that students engaged in the skills of science inquiry and were more likely to show an increase in conceptual learning through these practices.

Scientific inquiry is well grounded in research and current publications. Research conducted at an undergraduate level of future science educators in Kahramanmaras Sutcu
Imam University, Turkey (Ural, 2016) studied 37 students who completed two chemistry modules, one in guided inquiry laboratory experiments and the other in traditional laboratory experiments. The students were given pre-and post-assessments on anxiety, attitudes and achievement. The researcher devised methodologies to compare with a t-test student achievement through written tests, attitude and anxiety levels. Additionally, the researcher developed reflection questions for student journaling and interviews providing qualitative data. The study found that students’ attitudes improved towards Chemistry as observed in their positive reflections in their journals. Students significantly increased their academic achievement when instructed through scientific inquiry and students showed a decrease in their level of chemistry laboratory anxiety.

Other research compared traditional instruction to inquiry-based instruction of 40 female fifth-grade students from Kermanshah, Iran (Abdi, 2014). The investigator administered a pre- and post-assessment of 30 pre-identified items to 40 fifth graders after an eight-week instructional period. During this time, the 40 students were divided in half and one group was instructed with a scientific inquiry approach during one class period, while the other group was instructed with traditional lessons in another class period. The investigator found that the students instructed through the inquiry-based learning scored significantly higher on the same assessment than the other group. The information reviewed in this section was the framework for my treatment group as I applied much of the science inquiry in my methodology.
This investigation was designed to compare traditional teaching strategies to scientific inquiry teaching strategies for ninth grade earth science students at Helena High School, Montana. The earth science students used for this study were 51 students from two class periods that are consecutive during the day, period 5 and period 6. Period 5 has 24 students and Period 6 has 27 students. Of these students, ten have accommodations through Individual Education Plans from Special Education services due to at least one learning disability, and three have 504 plans for disabilities that are health related, such as anxiety or Attention Deficit Disorder. Out of the 51 students, 45 (88%) are Caucasian, two (4%) are Asian, three (6%) are Native Americans and one (less than 1%) individual is African American. I choose these two class periods because of the diversity in learning levels and similarity in class size. Helena High School is a Title I school with 19.4% of the student body qualifying for free/reduced meals, though in Helena High School only about half of students report this need. Of students reporting free/reduced, 17.9% receive title math transitions or reading lab as Supplemental Education Services. Of my students, 19.6% receive Supplemental Education Services. Students in my classes range in motivation and academic ability. Student grades for the fall semester were 11% failed with a 59% or lower, 9% earned a D (60-69%), 30% earned a C (70-79%), 36% earned a B (80-89%), and 15% earned an A (90-100%). For this AR, the Montana State University’s Institutional Review Board has given me exemption status (Appendix A). Additionally, I have been given approval from Helena High School’s Principal Steve Thennis to complete this project and exemption from informed consent (Appendix B).
All earth science students in the study design were taught one unit of study on Weather and Storms using traditional teaching strategies referred to as the non-treatment unit and a unit of study on Astronomy using scientific inquiry teaching strategies referred to as the treatment unit (Appendix C). The instruments used for collecting qualitative and quantitative data for this AR is shown in the hierarchal chart in Figure 1. As previously mentioned, my school district is implementing NGSS standards, of which the eight Science and Engineering Practices closely align with the skills of scientific inquiry (Llewellyn, 2013); therefore, these practices were considered scientific inquiry and applied to the treatment group. From these eight practices, I selected four to focus on, though all eight were applied in the treatment unit. The four practices discussed in the analysis are: 1. Asking Questions (for science) and Defining Problems (for engineering); 2. Planning and Carrying out Investigations; 3. Analyzing and Interpreting Data; and 4. Obtaining, Evaluating and Communicating Information.
Figure 1. The Action Research Data Collection Instruments used for the treatment and non-treatment units.

The treatment unit and non-treatment unit had similar activities. Students wrote daily work in their notebooks. Each student began the class period with a bell ringer, which entails writing a question on the board from the previous day’s lesson and answering the question in a detailed response in their notebook. In addition, students answer a question orally to the teacher or to their classmates as an exit question for the conclusion to the class period. The treatment unit was taught in 28 days and covered 13 learning targets (Appendix C), which are daily goals students should achieve regarding individual student understanding. The non-treatment unit was taught in 15 days and covered seven learning targets (Appendix C). The treatment unit and non-treatment unit
had similar types of activities though different teaching strategies were used in each unit (Table 1).

Table 1

| **Comparison of Instructional Strategies of Scientific Inquiry and Traditional** |
|---------------------------------|---------------------------------|
| Scientific Inquiry (Treatment Unit) | Traditional (Non-Treatment Unit) |
| Note-booking                     | Note-booking                    |
| Bell Ringers                     | Bell Ringers                    |
| Exit questions                   | Exit questions                  |
| 5E Learning Cycle                | Cookbook labs                   |
| Presentations                    | Presentations                   |
| Phenomena                        | Textbook questions.             |
| Misconception Probes             | Demonstrations                  |
| Modeling                         |                                 |
| Discourse and Sense Making       |                                 |
| Student-led Open Inquiry         |                                 |
| Teacher-led Inquiry              |                                 |

**Treatment Unit Methodology**

The treatment unit of study included different scientific inquiry strategies that have been shown to be effective in the classroom. One of these methods was the 5E Learning Cycle developed by Biological Sciences Curriculum Study and used to teach NGSS (Bybee, 2014). I taught four lessons of the 5E Learning Cycle, one of these lessons I taught was the Big Bang Theory. For the Engagement phase, students watched a film called “Expanding Universe,” to evoke student interest. Also, during the Engagement phase I demonstrated a phenomenon. I had students put on spectroscope glasses and I darkened the room. I used incandescent flashlights to show how the light spectrum changes in space relative to the viewer. For the Explore phase, students conducted a Doppler Effect lab. For the Explain phase I presented notes on the Big Bang Theory. For the Elaborate phase, students created a newscast recounting the Big Bang
and the evidence supporting the theory. For the Evaluation phase students completed a Big Bang Concept Map, in which they organized four words with connecting terms.

Another aspect of the treatment applied was work done by National Resource Council (2005) to increase conceptual understanding by misconception probes. This work showed that students bring to the classroom outside misconceptions that allow them to function within the content area, but do not allow them to learn the correct theory, concept or model. Part of the treatment was to unmask the misconceptions through probes, so they can be addressed, and the appropriate information retained. Probes were administered before the content was addressed and after to measure change. During probes, a teacher asks more questions to illicit more responses and gather a better understanding of students’ constructed views. The teacher should not correct students during the initial probe. Instead, they should correct students during the unit’s lessons. Four probes were used during the treatment unit. I discussed the results of two of these: “Is it a theory? (Keeley and Eberle 2008)” and “What happens when stars die? (Keeley & Sneider, 2012)”

Misconception probes were utilized to unmask students’ constructed views. Throughout the 5E Learning Cycle Instructional Model, students worked together to synthesize their thoughts through discourse and sense making. Evaluation of their sense making was done through modeling. Modeling can be as simple as diagraming the phenomenon or creating a three-dimensional representation of the phenomenon. Modeling was completed as exit questions, labs and project work.
I guided students in teacher-led inquiry and open-ended inquiry. Teacher-led inquiry is where students are given a scientific question and they plan and carry out an investigation, analyze data and draw conclusions from the data as it relates to their hypothesis to the original question. A more complex level of inquiry is open-ended inquiry (Grady, 2010). In this type of inquiry, the teacher gets students to ask their own research questions by inspiring their imaginations. Like teacher-led inquiry, students develop a hypothesis, plan and carry out an investigation, analyze the data and draw conclusions from this data.

The treatment unit on Astronomy was measured by multiple instruments (Table 2). At the start of the unit, students completed The Student Science Inquiry Survey, which was a modified science skills survey from Llewelyn (2008) with modern skills created by NGSS Science and Engineering Practices used to assess student confidence of 26 skills in the four Science and Engineering Practices (Appendix D). Then students completed a pre-test with 25 multiple choice questions. During the unit, I administered three types of Concept Attainment Techniques (CATs). The first CAT was a concept map and administered twice during the treatment unit. Concept mapping is an instrument that draws connections between concepts and information (Angelo and Cross, 1993). The specific concept map used is the “Concept Card Mapping” created by Page Keeley (2008) and used in the Classroom Assessment Techniques text (Cross and Angelo, 1993). Students were given four words in astronomy. They had to connect these terms with connecting phrases to make sense of the map. The second CAT was One-Sentence Summary developed by Cross and Angelo (1993). For the One-Sentence Summary,
students were given the task of writing a sentence that summarized the presentation. The third CAT was Muddiest Point developed by Cross and Angelo (1993). For the Muddiest Point, students wrote a question for something they did not understand in the presentation. For reliability purposes, both the One-Sentence Summary and Muddiest Point were administered earlier in the year and I found that student scores were consistent to their current grade and understanding. At the end of the unit students took a post-summative test that included the same 25 multiple choice questions as the pre-test for comparison purposes. The summative assessment was created by my earth science colleagues and I have proctored this test for three years. Two constructed response questions and one modeling question were added to the test to check for deeper learning. Students then completed The Student Science Inquiry Survey to see if their confidence in their science skills improved (Appendix D). Student interviews were conducted at the end of the unit (Appendix E) in which nine students were interviewed to gather incite on their attitudes, engagement and feelings toward teaching strategies. Students were selected for their achievement levels, in which a range of grades from A to D were present, whether they receive SES, and about an even percentage of boys and girls. Students then completed a Student Questionnaire (Likert-style) (Appendix F). Student were provided a statement and students responded with 1. Strongly Agree, 2. Agree, 3. Neutral, 4. Disagree and 5. Strongly Disagree. The questionnaire was a modified version from Handelsman, Briggs, Sullivan, and Towler, (2005) research on Biology student attitudes. To measure science skills, students completed an open-ended inquiry lab pre-assessment and then completed another open-ended inquiry lab as a post-assessment. Students were
given similar amounts of guidance for both labs and students were assessed by a lab rubric developed by the Helena High Science Department, and one that I have used for six years with ninth grade students and is reflective of their science skills. I amended the rubric to reflect the newly adopted NGSS this year.

Table 2

Research Triangulation Matrix of Instruments Used to Collect Data on AR

| RESEARCH QUESTIONS                                                                 | INTERVIEW | MIS- CONCEPTION | SUMMATIVE ASSESSMENT | FORMATIVE ASSESSMENT | QUESTIONNAIRE | SCIENCE SKILLS | SUMMARY | REFLECTION |
|----------------------------------------------------------------------------------|-----------|-----------------|----------------------|----------------------|---------------|----------------|---------|
| Essential Question How does teaching scientific inquiry through the 5E Learning Cycle effect 9th grade earth science students’ engagement and their conceptual understanding? | B²        | A¹, B           | A                    | A, B                 | A, B          | A, B           | B       |
| Sub-question #1 In what ways, does teaching science inquiry impact me as a teacher? | B         |                 |                      |                      |               |                | B       |
| Sub-question #2 What student attitudes are present during science inquiry lessons? | B         |                 |                      | A, B                 |               |                | B       |
| Sub-question #3 How are students’ science inquiry skills affected by this treatment? | A         | A, B            |                      |                      | A, B          |                | B       |

Note.¹ Quantitative Data. ² Qualitative Data.

Non-Treatment Unit Methodology

The non-treatment unit teaching strategies were considered traditional methods.

The subject matter for the non-treatment unit was Weather and Storms. Traditional teaching methods include presentations, cookbook labs (procedure is provided in lab for student to follow), demonstrations and textbook questions. Presentations were delivered via PowerPoint that students paraphrased or wrote down verbatim in their notebooks. Presentations covered the content that students learned during the unit. Presentations led
into a lab the following day. Labs are called cookbook labs because students need to follow each direction to complete the lab and collect data. Students analyze the data collected by graphing the results or doing calculations, then students answer conclusion questions. Textbook questions are delivered after each cookbook lab to relate the lab to the content of the unit and are found in the conclusion section of the lab. Demonstrations were shown to emphasize the concept and to excite the students about learning.

Data collection for the non-treatment unit was initiated by students taking a pre-assessment with 25 multiple choice questions over eight learning targets. During the unit, students completed the same three CATs for formative assessments as assessed in the treatment unit. The first CAT administered was a concept map on humidity in which students had to place four terms in a sensical sequence with connecting terms between each word. The second CAT was a One-Sentence Summary that students wrote after a presentation on wind. The third CAT was Muddiest Point, which was administered after the presentation on wind. At the end of the non-treatment unit the students completed a post-assessment that included the same 25 multiple choice questions as the pre-assessment. Two constructed response questions and one modeling question were added to the test to check for deeper learning. Students then completed The Student Science Inquiry Survey administered prior to the unit to see if their confidence in their science skills improved. Students then completed a Student Questionnaire at the end of the unit.

**Triangulation of research questions**

I used many different methodologies for this AR to compare the treatment unit with the non-treatment unit. The AR essential question and sub-questions #2 and #3 had
instruments created for triangulation purposes in which three or more tools are needed to answer the question. Sub-question #1 used only two instruments to answer the question due to the topic at hand (Table 2). Both quantitative data and qualitative data were gathered for each question. Quantitative data allows for statistical testing to find levels of significance while qualitative data can be used to support the statistics and to find trends in student attitudes, engagement and conceptual understanding. Moreover, the instruments allow for triangulation, in which three different observations for three different instruments are used for the question.

The essential question “How does teaching scientific inquiry through the 5E Learning Cycle affect ninth grade earth science student’s engagement and their understanding of concepts?” uses eight instruments to collect data. Misconception probes were used to expose student ideas from their constructed world to address these problems and attain conceptual understanding. Summative assessments were administered to gather data on students’ understanding of the unit’s content. Formative assessments such as Muddiest Point, One-Sentence Summary and Concept Mapping were administered to examine students’ conceptual understanding of individual learning targets as addressed by both the treatment and non-treatment lessons. And the Student Questionnaire (Likert-style) was administered to collect data on engagement in student learning.

The sub-questions were also investigated using different instruments. I gathered data from the first sub-question “In what ways, does teaching science inquiry impact me as a teacher?” by completing journal reflections (Appendix H) after daily lessons on feelings about the lesson, energy level at the end of the lesson, and thoughts on whether
lesson was well received by the students. The second sub-question, “What student attitudes are present during science inquiry lessons?” was evaluated by three instruments. A Student Questionnaire was utilized to quantitatively assess students’ attitudes towards scientific inquiry as compared with traditional lessons. The Student Questionnaire was administered after each unit of study. Students were interviewed after both units. Interview questions were created to gauge students’ attitude during traditional instruction compared with scientific inquiry instruction and to track changes in student views to see which lessons produce a more positive student environment. Additionally, Teacher Journal Reflections examined student attitudes daily. The third and final sub-question, “How are students’ science inquiry skills affected by this treatment?” was addressed by interviews, formative assessments and summative assessments. Interview questions were administered to gather evidence of how students’ think their science inquiry skills were at that time. Interviews also provided quotes from students to support other instrument data.

**DATA AND ANALYSIS**

This data and analysis section is organized by the AR essential question “How does teaching scientific inquiry through the 5E Learning Cycle and other strategies affect 9th grade earth science students’ engagement and their conceptual understanding?” and the three sub questions “1. In what ways, does teaching science inquiry impact me as a teacher?” 2. “What student attitudes are present during science inquiry lessons?” and 3. “How are students’ science inquiry skills affected by this treatment?”
AR Essential Question

Data for the AR essential question came from many different instruments and will be analyzed separately. The non-treatment unit was taught during second quarter while the treatment unit was taught during third quarter. The average student grade for the second quarter was 79% while the average student grade for the third quarter was 75%. The difference of only four percentage points is not considered significant.

The first instrument was the pre-assessment and post-assessments summative unit test administered for the non-treatment unit of Weather and Storms and the treatment unit of Astronomy (Table 3). The average post-assessment score for the group of the non-treatment unit was 58.3% while the average post-assessment for the treatment unit was 75.5%. The pre-assessment average for the non-treatment unit was 35.8% while the average pre-assessment for the treatment unit was 45.3%. The average normalized gains for the non-treatment unit were 36.9% as compared to the average normalized gains for the treatment unit of 55.2%, a significant difference (p-value of 0.00012). Average normalized gains for this AR were calculated by subtracting pre-assessment from post-assessment, then dividing the quantity of 100% minus the pre-assessment. All p-value calculations for this AR were derived from a T-test. The takeaway from these tests is that the students did much better on the science inquiry taught unit than on the traditionally taught unit. In comparison of difficulty, both units covered 0.5 learning targets per day, the treatment unit length was 13 days longer than the non-treatment unit, and I observed students having great difficulty with the learning targets related to relative humidity in the non-treatment unit.
Table 3
Comparison of Pre- and Post-Summative Assessments and Normalized Gains for Treatment and Non-Treatment Units (N=44)

<table>
<thead>
<tr>
<th></th>
<th>Non-Treatment,</th>
<th>Treatment</th>
<th>Non-Treatment</th>
<th>Treatment</th>
<th>Non-Treatment</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-Test (%)</td>
<td>Pre-Test</td>
<td>Post-Test (%)</td>
<td>Post-Test</td>
<td>Test</td>
<td>Normalized Gains (%)</td>
</tr>
<tr>
<td>Average</td>
<td>35.8</td>
<td>45.3</td>
<td>58.3</td>
<td>75.5</td>
<td>36.9</td>
<td>55.2</td>
</tr>
<tr>
<td>Median</td>
<td>34.8</td>
<td>44.0</td>
<td>59.1</td>
<td>80.0</td>
<td>40.3</td>
<td>58.3</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>16.2</td>
<td>14.2</td>
<td>17.2</td>
<td>14.4</td>
<td>23.8</td>
<td>21.7</td>
</tr>
</tbody>
</table>

Concept maps were another tool used to assess conceptual understanding, specifically administered to gather data on students’ ability to connect terms (Figure 2).

The non-treatment concept map that assessed students conceptual understanding of humidity had an average score of 66.8% (standard deviation was 21.2%). The treatment concept map that assessed students’ conceptual understanding of nuclear fusion had an average score of 85% (standard deviation was 13.2%), 18.2 percentage points higher than the non-treatment concept map on humidity (p-value = 7.5 x 10⁻⁵). That is a very significant difference. Additionally, the second concept map in the treatment unit which assessed student understanding of scientific theory had an average score of 87.5% (standard deviation was 17.1 %), 20.7 percentage points higher than the non-treatment concept map on humidity (p-value = 0.0003). Like the summative assessment, the treatment unit’s concept maps show that students had a better conceptual understanding during the science inquiry unit.
Two CATs were administered together during both units, “The Muddiest Point” and “One-Sentence Summary.” They were used after I presented content to the students through demonstrations and presentations. The non-treatment presentation’s learning target was “I can understand high and low pressure and how pressure differences can cause weather.” The students one sentence summaries were marked either correct or incorrect; 47% of the students’ sentences were correct. The closest responses to the One-Sentence Summary were two students who wrote the exact learning target addressed in the presentation. Other answers considered acceptable were “How air pressure affects the formation of clouds and land,” “Difference in high and low pressure,” “Types of air pressure and the movement characteristics of it,” and “High and low air pressure.” Examples of student answers not considered acceptable were “air pressure,” “High air pressure goes clockwise and outwards and sinks while low is vice versa,” and “How clouds are formed.” The second CAT was the muddiest point in which only 46% of
students surveyed wrote a question or statement they had trouble understanding such as “difference between high and low air,” “how wind works?” “How the vacuum works?” and “How does Rain Shadow affect work?” Thirty one percent of the students either did not have a muddiest point or were not able to come up with a question. Eleven percent said they understood everything. Comparatively, the treatment unit’s presentation’s learning target was “I can analyze star composition through spectroscopy “and “I can model the life cycle of the star.” For the one-sentence summary CAT, twenty-four percent (n=46) of the students were considered correct, 23 percentage points lower than the non-treatment unit. Answers deemed acceptable were “What makes up stars and their different types,” “The process of how we study stars, the colors, and more about the life of the stars,” and “Scientists use many methods to determine characteristics of stars.” Students’ answers that were considered incorrect included “The distance of stars” and “life cycle of stars.” Students also wrote their muddiest point for this presentation, in which 33% either wrote “nothing” or left it blank and 13% said “I got everything.” The remainder of the students (54%) wrote their “muddiest point” which was a seven percentage point increase from the non-treatment group. Students wrote “What happens to planets after the main sequence star phase?” “What is a black hole?” “How people are made of stars.” This data suggests it is hard for ninth graders to understand the main idea by writing a one-sentence summary of presentations. However, the fact that students in the treatment unit asked more questions suggests that they were more engaged.

Another measure of conceptual understanding was the use of misconception probes. Misconception probes are used when teaching Science Inquiry not in traditional
instruction; therefore, a comparison is not applicable here. The two misconception probes administered were “Is it a Theory (Figure 3),” and “What Happens to Stars When they Die (Figure 4).” Prior to teaching the learning target, the probe was administered. Then I taught the lesson and students were re-evaluated using the same probe.

*Correct answer to the prompt.

**Figure 3.** Pre- and post-assessment of the Misconception Probe “Is it a Theory?”, (N=20). *Correct answer to the prompt.*
Figure 4. Pre- and post-assessment of the Misconception Probe “What Happens to Stars When They Die?”, (N=30). *Correct answer to the prompt.

Four correct answers existed to “Is it a Theory” probe. The first correct answer, “Theories are inferred explanations, strongly supported by evidence,” increased by one in the post-assessment from 19 to 20 student responses. The second correct answer, “Theories have been tested many times,” increased by three in the post-assessment from 17 to 20 student responses. The third correct answer, “Theories include observations,” did not change at 20 student responses. And the fourth correct answer, “Theories are used to make predictions,” decreased by one from 19 to 18 student responses.

Interestingly, one of the highest number of responses for a wrong answer student selected was “Scientific law has been proven and a theory has not,” and it did not change from pre- and post-assessment at 13 student responses. And, of note, “Theories can include personal beliefs and opinions,” had a decrease of five student responses from nine to five.
The other misconception probe was similar in format and it too had four correct answers that students could choose. Of these four correct answers, two answers increased in student responses from pre- and post-assessment, while two answers decreased in student responses. The first correct answer was “stars can expand and get bigger right before they die,” which increased by five in student responses from 17 to 22. The second correct answer that increased was “A dying star can become a black hole,” going from 22 to 27, a total of five student responses. The third correct answer was “Dying stars can explode,” which decreased by six from pre- and post-assessment going from 29 to 23. The fourth correct answer, “Dying stars get dimmer and dimmer and finally stop glowing,” also decreased by eight, from 19 to 11. In comparison of the two, student responses to “Is it a theory” probe improved in selection of correct answers. And though the “What Happens to Stars When They Die” did have improved results for two of the prompts, the other two showed a decrease. The misconception probes show that misconception can be changed if the content is taught properly and they also show that misconceptions are difficult for students to change their constructed view.

Students responded to ten Likert value statements in the Science Questionnaire at the beginning of the treatment unit (pre-assessment) and again at the end of the treatment unit (post-assessment) to measure student attitudes to teaching methods (Figure 5). For these Likert value statements, students wrote a number from one to five of how they felt. One was strongly agree, two was agree, three was neutral, four was disagree and five was strongly disagree. An additional ten statements were used to measure engagement (Figure 6). Student attitudes to teaching methods will be discussed first. Between the
pre-assessment and post-assessment, there was not much difference in overall scores (p-value = 0.404), though there were big differences in specific questions such as number 22.” I am more interested in labs when I write my own research questions and hypothesis.” The average score during the pre-assessment was a 2.97 as compared to 2.6 in the post-assessment and the number of students who strongly agreed increased from four to nine. Another question that showed change was 27,” I learn the concept better when I research science concepts on my own.” It had an average pre-assessment score of 2.9 and an average post-assessment score of 3.2. Even though the average score increased, there was an increase in students who strongly agreed with this statement from four to eight. Students responses to 23,” I like labs more when I write my own directions instead of following directions already written for the lab” regarding learning and attitude changed slightly. The pre-assessment average was 2.9 and the post-assessment was 3.2. Also worth noting is that students averaged a 2.3 in pre- and post-assessment for question 28,“ I learn better when I discuss the information with my group.” Eleven students strongly agreed with the question in the post-assessment. Student responses show that they are more interested in writing their own research questions after experiencing this in the treatment group and that students feel they learn better when they discuss answers with the group.
21. For me, earth science is primarily about learning known facts as opposed to investigating the unknown.
22. I am more interested in labs when I write my own research questions and hypothesis.
23. I like labs more when I write my own directions instead of following directions already written for the lab.
24. I learn more when I write my own directions instead of following directions already written.
25. I would rather research science concepts than have the teacher present the concept by notes.
26. I learn the concept better when I research science concepts on my own.
27. I learn the concept better when the teacher presents the concept by notes.
28. I learn better when I discuss the information with my group.
29. I am open to learning new information about earth science even if it goes against my beliefs.
30. I like to ask questions about the natural world.

Figure 5. Student questionnaire Likert value responses for pre- and post-assessment for teaching methods, (N=39).
Figure 6. Student questionnaire Likert value responses for pre- and post-assessment for engagement, (N=39).

11. When I am answering an earth science question, I find it difficult to put what I know into my own words.
12. If I get stuck on answering an earth science question on my first try, I usually try to figure out a different way that works until I get it.
13. Learning earth science changes my ideas about how the natural world works.
14. Working with lab partners and in small groups helps me learn the concept.
15. Choosing my own lab partners and small group improve my ability to learn.
16. I am confident that I can do well in earth science class.
17. I am putting forth a lot of energy to do well in earth science class.
18. I listen carefully in class.
19. I study earth science on a regular basis.
20. I work hard to understand the concept because I want to learn earth science.

Responses to the Student Questionnaire for engagement also showed interesting results. When comparing pre-assessment to post-assessment in engagement, there was not a significant difference (p-value = 0.34) between the two questionnaires. The greatest difference between the pre- and post-assessment was statement 12, “If I get stuck on answering an earth science question on my first try, I usually try to figure out a different way that works until I get it.” The average of the pre-assessment was 2.7 while the average of the post-assessment was 2.5. The post-assessment responses leaned more towards “strongly agree” than in the pre-assessment, meaning students were more apt to figure out a unique way that works until they get it. Conversely, statement 15, “Choosing
my own lab partners and small groups helps me learn the concept,” had an average pre-assessment score of 2.6 and an average post-assessment score of 1.8. This shows that students felt that choosing their own partners and small groups was not as important as in the post-assessment. Students responses from the post-assessment to 14,” Working with lab partners and in small groups helps me learn the concept,” had the second highest frequency of responses to strongly agree and had an average student response scores of 2.1. I think the reason for this is that students learn from each other and feel more comfortable sharing their ideas through discourse in small groups instead of as an individual or classroom. Statements 20,” I work hard to understand the concept because I want to learn earth science,” with an average pre- and post-assessment score of 2.6, and 18,” I listen carefully in class,” with an average pre- and post-assessment score of 2.2, demonstrate that students are trying to engage in earth science. The Student Questionnaire provides critical data on students’ opinion of how they learn better and what their opinion is on different teaching methods, which gives prospective on why some students are doing better than others.

Another instrument used to assess student engagement was interviews on twelve different questions (Appendix G). Of these, seven were asked to gain a better understanding of students’ engagement in science and how they learn a concept. Of the nine students interviewed, seven of these students thought science is interesting and two of them thought some areas of science were interesting. Students found science to be interesting because of the open-ended questions, big thinking, astronomy and the Big Bang and just knowing how the natural world works. Six students thought astronomy
was the most interesting subject, atmosphere, geology and climate change were also noted. Student 1 said they liked astronomy because it is “open-minded to new discovery, Big Bang theory could change, and astronomy makes me realize how small we are.”

When asked if they were engaged in science class, all nine said they were. Student one said, “astronomy is fun to learn, “student 4 said they are engaged because of “hard questions with no answer to question” and student 6 said “notes are the most engaging.”

When asked to specify the most engaging activity, four students said labs. When asked “do you feel engaged in learning in group work or individual work? “Students said that they feel more engaged in group work than working independently. Though four students had a similar response as student 2, “depends on who you work with, bad if you have someone that is not working. I would rather pick my partner.” Students were then asked “do you like taking notes? Do you think notes help you learn?” The answers varied from yes and OK to no and I don’t care. One thing in common about notes was that students thought they helped them learn, such as this comment from student 2, “I don’t care, it is really easy, can look back on it for quizzes, definitely helpful.”

The final question from the interview regarding engagement was “What helps you learn a concept?” Student 8 said “explain it and do a demonstration.” This comment was similar to three others, in which students wanted to see the concept visually and make it hands on. Two individuals thought having individual attention on the concept was the most important for them to learn it. Question 12, “does your brain ever hurt because you are thinking so hard?” was used to see if students felt the cognitive disequilibrium that is desired in learning. Students did not express having that feeling in science, though some
students’ brains hurt due to being rushed to get done, not to understand a concept. This interview really sheds light on the type of activities students are engaged in and the method they perceive to be most helpful in their learning. The main take away was that students think notes help their learning and that students were engaged in hands-on activities. Interviews provide the qualitative data to support specific instructional activities.

The last instrument used to examine the essential question was the Teacher Journal Reflection. I reflected each day of the study period by answering eight questions. Of these, four were reflected through comments and given an associated Likert value number from 1-5. One was strongly disagree, two was disagree, three was neutral, four was agree and five was strongly agree. The treatment unit averaged a 3.9 Likert value (Figure 6), and the non-treatment unit averaged 3.6 Likert value. For both units the most common Likert value given was a 4. In the non-treatment group, students were highly engaged in hands-on activities such as can crushing (5 Likert value) and the “Cloud in the bottle lab. (4 Likert value)” In both of these activities, students were working with exciting natural phenomenon. Students were also engaged during these activities kinesthetically, by squeezing bottles and lighting matches. Teacher presentations were another activity that highly engaged students. For example, students asked great questions during the presentation on the Coriolis effect and were paying great attention while I demonstrated the cloud in the bottle (4 Likert value) in which one student said “wow.” Conversely, students were not engaged during a teacher presentation on wind (1 Likert value), in which students were not listening and exhibited off-task behavior. For
this lesson, I felt that I tried to teach too much and the concept was too hard for students to understand. The treatment group had similar levels of engagement. Students were highly engaged in the open-ended inquiry lab on impact craters (5 Likert value) and period of orbit (4 Likert value); almost all students were participating and worked well with their lab partners. Once again, students demonstrated their engagement in teacher presentations on the Big Bang theory (4 Likert value) by asking a lot of questions for understanding about the unknown. Project work was another activity in which students showed tremendous engagement. Students completed a solar system project (5 Likert value), Big Bang News Cast (4 Likert value) and the Science Circus project (5 Likert value). Students asked a lot of clarifying questions and they enjoyed researching content in which they were interested. Additionally, students worked hard to understand a concept when they had to present for the Big Bang News Cast. However, the treatment unit had lessons that lacked engagement, such as when I administered a misconception probe that was review for most students, though this was a day after the Super Bowl which tends to have low student engagement. Another day that lacked engagement was the second day of “Period of Orbit” space lab, which many students had already completed, some had already given up and others were getting bad data. During a presentation on Kepler’s laws (3Likert value) that I was unfamiliar with, students did not ask many questions and showed disinterest. The engagement of students during both units varied by activity and content, and this engagement impacted the teacher positively and negatively.
Sub-question 1: In what ways, does teaching science inquiry impact me as a teacher?

The instrument used to analyze how teaching science inquiry impacted me as a teacher was my Teacher Journal Reflections, in which I reflected on the eight questions at the end of the day. Of these eight questions (Figure 7) three demonstrated teaching science inquiry affected me as teacher: on whether I was able to show passion for the lesson, the level of enjoyment I received from the lesson and the amount of energy I had at the end of the day. During the non-treatment and the treatment unit I had similar average energy levels; the treatment group averaged 3.5 Likert value while the non-treatment group was 3.4 Likert value. In my reflection I noted that when students were engaged and had good attitudes, my energy level was higher. Conversely, on days that attitude and engagement were lower, my energy level was lower. For example, during the relative humidity lab in the non-treatment unit, students had a tough time understanding the lab and were off-task and my energy level was low (2 Likert value). Conversely, on a day when I presented and did a demonstration on clouds in the non-treatment unit, the students had a good attitude and were engaged, I had high energy (4 Likert value). Likewise, during the treatment group, when students were engaged in projects such as during the Science Circus project (worked independently), Solar System Project (worked independently) and Big Bang News Cast (worked with a team) my energy level was high (4 Likert value).
Daily lessons also can positively or negatively affect my ability to show my passion through science teaching. The reflection question, “Was I able to show my passion of science through this lesson,” had the lowest average Likert value of the three. I was able to show great passion for lessons such as Period of Orbit lab in which I enjoyed the research questions, kinesthetic value and its application to the natural world. Presentation of content that interested me, such as scientific theories and the Sun, also scored high on the Likert value (4). I was able to really get into these presentations and present with charisma and energy. Conversely, in presentations on content that I did not have a firm understanding of, my passion was low and student engagement and attitude were lower. Then there were lessons, such as a “Life Cycle of Stars” internet assignment that kids were engaged in and working independently, but as a teacher, I was not actively participating and was not able to show my passion because I was not participating in their learning.
Another aspect that impacted me as a teacher was whether I enjoyed the lesson, which averaged a 3.5 Likert value scale and seemed to mirror student attitude and engagement. For instance, I presented on the Big Bang as a scientific theory and students were highly engaged (4 Likert value) by asking lots of questions and they had good attitudes (4 Likert value) and my enjoyment was high (4 Likert value). Similarly, this was true for all project days, Period of Orbit lab, the nuclear fusion model, presentations on the Sun and Life Cycle of Stars. Days when my enjoyment was lower were reflected by kids being off-task or students not understanding the concept. For example, I attempted a phenomenon of gravity and students were not engaged because they had already seen it. Their engagement was low, which resulted in my low enjoyment. The other lesson in the treatment unit where I recorded low enjoyment was a presentation on Kepler’s laws, which I did not completely understand, and student engagement and attitude were low. The Teacher Journal Reflection provided a means to discuss my opinions from the day’s lesson. I was able to reflect on my energy level, my passion and my enjoyment for the day, which is very important in determining my teaching strategies.

Sub-question 2: What student attitudes are present during science inquiry lessons?

Student attitudes were assessed using ten Likert value style questions completed as a pre- and post-assessment of the treatment unit, student interview questions on attitude administered at the end of the treatment unit, and teacher journal reflections completed daily. The post-treatment student questionnaire was significantly different from the pre-treatment (p=0.004; N=39) as measured by a t-test showing a negative trend from pre- and post-assessment. The ten statements (Figure 8) all had an average score of
under 3 Likert value (neutral) and nine of the ten scores were higher for the post-treatment compared to pre-treatment. Of these nine statements the greatest difference in attitude from pre-treatment to post-treatment were: 3, “Earth science class is fun,” which pre-treatment had an average score of 2.5 Likert value compared with the post-treatment of 2.9 Likert value; 5, “I enjoy figuring out answers to earth science questions,” which had a pre-treatment average score of 2.6 Likert value compared with 2.9 Likert value post-treatment; and 8, “I enjoy working with lab partners and in small groups,” which had a pre-treatment average score of 1.9 Likert value compared with a 2.2 Likert value post-treatment. The only score to decrease in the post-treatment survey was 9, “Earth science is easy for me to learn and do well in the class,” which had a pre-treatment average score of 2.7 Likert value compared with a post-treatment average score of 2.4 Likert value.
Figure 8. Student questionnaire responses of attitude for pre- and post-assessment of treatment unit, (N=39).

1. I really like school.
2. Earth science is very interesting to me.
3. Earth science class is fun.
4. In general, I have a good feeling toward earth science.
5. I enjoy figuring out answers to earth science questions.
6. I feel comfortable to ask questions or share my opinion in class.
7. I feel welcome and comfortable in this class.
8. I enjoy working with lab partners and in small groups.
9. Earth science is easy for me to learn and do well in the class.
10. I think the skills and content I learn in earth science are important to my life after high school.

The student interview (N=9) had five questions designed for students to reflect on their attitude to science class and school in general (Appendix G). All but one student interviewed said they liked school. The students interviewed who liked school said they liked it for the social aspect, freedom, electives and the education. Student 6 said “I like the social side and freedom and dislike homework.” Student 7 was the one student who said they did not like school; however, she did enjoy the learning aspect but “disliked environment and peers.” The other students when probed further about what they disliked said homework and other students’ bad behavior. The activities the nine students said
they liked were labs, demonstrations and projects. Students liked the hands-on component of the labs because they were visual and helped them learn. One student liked labs because they benefited from the discussion with their partner. Seven of the nine students interviewed said they disliked notes. Student reasons varied from “need to give notes in smaller amounts” and “the teacher went too fast” so the student was unable to pay attention. Student 5 did not like labs that they create themselves because he said it is “easy to get lost, easier with instructions.” Seven of the nine students thought science class is fun while two students said that science is fun sometimes. The students thought labs, moving and being outside, building models and the science circus project were fun; student 6 said that creating labs in science inquiry was fun. Student attitudes toward science inquiry labs, where you design your own experiment and labs where the procedure was provided, were varied. Three students liked both types; four thought designing their own experiment was better, and two students preferred to have the procedure provided. Student 3 liked both but when referencing create his own he said it gave him “more freedom.” Conversely, student 9 prefers the procedure provided because “then the teacher knows the answer instead of getting wrong data.” The interview responses provided student opinions on their attitude toward science and the students gave specific rationale for their answers which is used to support the research findings.

My Teacher Journal Reflections looked closely at student attitude. One of these Teacher Journal Reflection questions read: “did students have a good attitude?” in which I scored a Likert value and explained why I ranked the day with that value. The average score of the non-treatment unit was 3.6 Likert value and the treatment unit average score
was 3.7 Likert value. For the non-treatment unit, students had good attitudes for presentations and demonstrations. For example, for the topic of clouds and my “cloud in a jar” demonstration, students were in good moods and the “wow” factor was noticed. Students liked the air pressure presentation with the demonstrations of a vacuum and the “spoutin’ fountain” demonstrating effects of high and low pressure. Students also had good attitudes for labs and they seemed to love the movement and Bunsen burners for the “Can Crushing” lab, which I gave a 5 Likert value on their attitudes. Students had more neutral attitudes and exhibited off-task behavior during the wind presentation in which I felt that it was too hard of a concept and I tried to teach too much. The lowest attitude score was during the relative humidity lab in which students were confused and were very off-task. For the treatment unit, students had the best attitudes during the open-ended inquiry lab called “Impact crater lab” and they had fun with the flour and the impact of the object measured. Students really got excited for the other open-ended inquiry lab, “Period of Orbit.” This lab is my favorite of all labs in the earth science curriculum. Other activities in which students had good attitudes were the presentations of the Big Bang and the Doppler effect in which students asked a lot of questions and showed curiosity for the unknown. For a full-week, students had strong attitudes doing their own independent research where they came up with their own questions to guide them. Student attitudes did decrease the day after the Super Bowl and on the second day of the “Period of Orbit” lab when students finished early, and others had to still complete their work. Students exhibited their worst attitude during a presentation on Kepler’s laws in which they were grumbling a lot, and I felt that I did not understand the content well
enough and the content was math heavy. High student attitudes during presentations were surprising to me because I think that students do not have the attention span.

**Sub-question 3: How are students’ science inquiry skills affected by this treatment?**

Science skills define Science Inquiry; therefore, it is important to measure student progress regarding these skills. Students completed a pre-assessment open inquiry lab called “Impact Crater” at the beginning of the treatment unit and a post-assessment open inquiry lab was administered in the Earthquake/Volcanoes Unit which followed the treatment unit in sequence and was called “Earthquake Prediction Lab.” Both labs were scored with the same lab rubric and results are presented in Figure 9. The average score for the pre-assessment was 46.7% (standard deviation of 25.5%) with a post-assessment average score of 74.6% (standard deviation of 22.7%). The normalized gains from the pre-to the post-assessment was 58.1% (N=30). The lab rubric assessed five components (Figure 10) of the lab and students improved in each component on a scale of 1 (lowest)-4 (highest). The Introduction, which included the question and hypothesis and assessed the practice, Asking Questions, student scores increased by 0.8 points from pre-assessment to post-assessment. The section titled Methods and Data Collection assessed the practice, Planning and Carrying out an Investigation. Students increased by 1.6 points and 0.7 points, respectively, from the pre-assessment to the post-assessment. In Analyzing and Interpreting Data, students increased by 1.6 points. The final category, Conclusion, increased by 0.8 points, and assessed the practice, Obtaining, Evaluating and Communicating Information. These results show a substantial increase in students’ ability to complete an open-ended inquiry lab demonstrating an increase in science skills.
Students increased in science skill, but how does this compare to their confidence.

The Student Science Inquiry Survey was designed to assess student confidence levels in the four measured practices from “I am very confident in my abilities,” ”I am somewhat confident in my abilities,” and “I am not confident in my abilities.” The survey was given as a pre-assessment before the non-treatment unit, as a mid-assessment.
administered before the treatment unit and as a post-assessment at the end of the treatment unit (Appendix D). For the purposes of this analysis, I compared student scores from the mid-assessment taken prior to the treatment unit to the post-assessment taken after the treatment unit was completed. Students assessed their confidence for 26 skills in four Science and Engineering Practices. Students completed the survey in less than ten minutes, and it was broken down into the averages of student response regarding confidence (Table 4). The data shows that students that responded “I am very confident in my abilities” increased by 6.1 percentage points from 41.3 to 47.4 in Asking Questions. Students decreased by 3.3 percentage points from 54.6% to 51.3%, in Planning and Carrying out Investigations. Once again students decreased from 43.0% to 42.6% in Analyzing and Interpreting Data. And decreased from 49.7% to 47.0% in Obtaining, Evaluating and Communicating Information.

Looking more closely within the practice of Asking Questions, the skill “creating scientific investigation type questions” had a pre-score of 22%, mid score of 30.2% and a post score of 45.5% climbing 23.5 percentage points through the duration of data collection and 15.3 percentage points during the treatment unit. Within the Planning and Carrying out Investigations practice, “assuming leadership role” rose from 33% at pre- to 48.8% at mid- and post- was 50% rising a total of 17 percentage points during data collection and 1.2% during treatment. Another skill, “analyze data to provide evidence for phenomena” within the practice Analyzing and Interpreting Data, started at 18% as a pre-, rose to 32.5% at mid-, and by post- was up to 48.8%, climbing a total of 30.8 percentage points with a 16.3 percentage point increase during the treatment group.
Finally, the skill, “close read scientific literature to determine the key points and supporting details,” went from 34% pre, 42.5% mid and 47.5% post, which is a total of 13.6 percentage point increase with 5.1 percentage points of that during treatment unit.

Table 4
The Student Science Inquiry Survey Percentage of Students’ Level of Confidence During Pre-, Mid-, and Post-Assessment

<table>
<thead>
<tr>
<th>NGSS Science and Engineering Practice</th>
<th>I am very confident in my abilities Pre (%)</th>
<th>I am very confident in my abilities Mid (%)</th>
<th>I am very confident in my abilities Post (%)</th>
<th>I am somewhat confident in my abilities Pre (%)</th>
<th>I am somewhat confident in my abilities Mid (%)</th>
<th>I am somewhat confident in my abilities Post (%)</th>
<th>I am not confident in my abilities Pre (%)</th>
<th>I am not confident in my abilities Mid (%)</th>
<th>I am not confident in my abilities Post (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asking Questioning</td>
<td>44.3</td>
<td>41.3</td>
<td>47.4</td>
<td>53.0</td>
<td>48.3</td>
<td>42.4</td>
<td>2.5</td>
<td>10.5</td>
<td>10.2</td>
</tr>
<tr>
<td>Planning and Carrying out Investigations</td>
<td>53.7</td>
<td>54.6</td>
<td>51.3</td>
<td>38.8</td>
<td>35.5</td>
<td>44.3</td>
<td>8.5</td>
<td>9.7</td>
<td>8.8</td>
</tr>
<tr>
<td>Analyzing and Interpreting Data</td>
<td>35.0</td>
<td>43.0</td>
<td>42.6</td>
<td>54.4</td>
<td>44.5</td>
<td>52.2</td>
<td>10.5</td>
<td>12.5</td>
<td>5.2</td>
</tr>
<tr>
<td>Obtaining, Evaluating and Communicating Information</td>
<td>37.5</td>
<td>49.7</td>
<td>47.0</td>
<td>56.0</td>
<td>45.4</td>
<td>47.1</td>
<td>8.0</td>
<td>4.9</td>
<td>8.8</td>
</tr>
</tbody>
</table>

Note. (N=44).

How does student confidence in science skills compare to their actual skills as measured in open-ended inquiry lab write ups (Figure 11)? Sixty two percent of students scored 4 out of 4 in the introduction (Asking Questions), while 47.4% were very confident in this skill. The percentage of students that scored 4 out of 4 in methods (Planning and Carrying out Investigations) was 51.4, 48.6% scored 4 out of 4 in data collection (Planning and Carrying out Investigations), while 51.3% were very confident in this skill. The percentage of students that scored a 4 out of 4 in analysis (Analyzing and Interpreting data) was 40.4, while 42.6% were very confident in this skill. The lowest area scored was 24% of students scored a 4 out of 4 in the conclusion (Obtaining, Evaluating and Communicating Information), 47% who felt very confident in this skill.
These comparisons are important to address as students who are overconfident may not work as hard on these skills in the future.

Figure 11. Science Inquiry Lab evaluation components for post-assessment, \((N=37)\).

### INTERPRETATION AND CONCLUSION

**AR Essential Question**

The interpretation and conclusion will focus on the AR essential question: “How does teaching scientific inquiry through the 5E Learning Cycle and other strategies affect ninth grade earth science students’ engagement and their conceptual understanding?”

The results from the instruments used support that students had an increase in conceptual understanding in the scientific inquiry taught unit as compared with traditional instruction. The average normalized gains had a significant difference from the non-treatment unit (36.9%) to the treatment unit (55.2%). Moreover, students in the treatment unit scored significantly higher than students in the non-treatment unit on the two concept map assessments. Granted, students scored higher on the non-treatment unit in “One-Sentence Summary” though this was more a snapshot in understanding a presentation
than the other more developed assessments. The 5E learning cycle focuses on two or three learning targets for a longer duration than traditional instruction and students may delve deeper into the subject matter and gain a better conceptual understanding. These findings support what Minner, Levy and Century (2009) found in 51 studies, which was a positive improvement in student learning. Conceptual understanding may have been increased in both units if I did a better job of addressing student misconceptions. These misconceptions affect student learning (Llewellyn, 2013). My results showed that misconceptions did decrease from pre- to post-assessment using the misconception probes. Though if I spent more time addressing these misconceptions I feel that students conceptual understanding would increase.

An increase in conceptual understanding through science inquiry is evident in the results. However, only certain areas show that engagement levels increase with science inquiry. For example, after a presentation in the non-treatment unit on air pressure and a presentation on stars in the treatment unit, students in the non-treatment unit had more questions in Muddiest Point with a seven-percentage point difference. More students came up with a question they did not understand indicating that they were more engaged and cared about the material. Students also expressed that they were more interested in science inquiry labs. In the Student Questionnaire, students’ scores tended more toward “strongly agree” in the post-assessment on “I am more interested in labs when I write my own research questions and hypothesis.” An increase in student engagement in science inquiry labs was also noted in the interviews. More students said that they liked labs in
which they were able to ask their own questions than labs where the teacher provided procedure. They also felt more engaged in these labs because of their invested interest.

Results also showed that similar student engagement occurs in activities that are taught in science inquiry instruction and traditional instruction. From the perspective of the teacher in the Teacher Journal Reflections, students were engaged in both units with presentations and labs. For example, students were very interested in the cloud presentation and especially the accompanying demonstration in the non-treatment unit. Likewise, students were engaged in the presentation on stars and nuclear fusion in the treatment unit. Students seemed to find this information interesting so they asked questions and listened intently. The Teacher Journal Reflections also show that students are engaged similarly in “cookbook” labs and open-ended inquiry labs. Students like to move around and do science. Project work is another area in which students are engaged and, though it was only taught in the treatment unit, these types of projects have drawn great engagement in other units that I have taught. In the student questionnaire, students responded that they more strongly agreed to two statements that had an underpinning of engagement. One statement averaged a 2.2 Likert value “I listen carefully,” and a 2.6 average Likert value for “I work hard to understand the concept because I want to learn.” These two statements demonstrate that students are engaged in their learning in all types of teaching strategies, though this engagement may not be perceived by the teacher.

Activities and teaching strategies have influence on student engagement and so does working with others. Student engagement is higher when students are working together, and students feel that they can learn the material better with partners. Students
more strongly agree (1.8 Likert value) with “choosing my own lab partners and small
groups helps me learn the concept,” and “I learn better when I discuss the information
with my group, which was a 2.3 Likert value. Student engagement can be high in
teaching strategies that have interesting presentations, get students involved in collecting
data in labs and having students involved in project work.

I believe that the claims I have made in this paper have substantial evidence with
sound reasoning. However, an aspect of the study worthy of further discussion is the
validity of comparing the treatment unit with content of astronomy to the non-treatment
unit with content of weather and storms. This comparison of these two units may be
weakened by the study design for these reasons: the astronomy unit was 23 days as
compared to the weather and storms unit of 13 days; and the content was not the same.
In reflection, a change I would make in the methodology would be to teach two class
periods as the treatment group and two class periods as the non-treatment group with the
same content. This would allow for a direct comparison between the two teaching
methodologies (i.e. Treatment and Non-treatment) and not be biased by content covered.
I contemplated this design, however I decided that I wanted to be fair to all students for
grading purposes, so I taught each class similar. Additionally, I wanted to compare the
weather and storms unit that I have taught more traditionally for many years in a row to a
newly designed unit in astronomy based on scientific inquiry teaching strategies.

Sub-question 1: In what ways, does teaching science
inquiry impact me as a teacher?

Science teaching impacts me in multiple ways and for this project I reflected on
three aspects that affect me. The first is how my energy is at the end of the day. I found
that my energy level was similar in both units. So, teaching strategies were not as important as the activities students were completing. I found that if students were engaged by asking questions and had good attitudes, such as during the cloud presentation and period of orbit lab, then I had high energy at the end of the day. Conversely, I had low energy on two days that I presented material that I was unsure of and that was not as interesting. This led to students’ being off-task. The other important way that teaching impacts me is if I can show my passion for science. I found that I was able to show passion in both units and, not surprisingly, I was able to show my passion during presentations into which I put a lot of energy and that I thought were interesting. Moreover, I was very passionate about a science inquiry teaching strategy on an open-ended inquiry lab called “Period of Orbit.” I am passionate about teaching how to do science and I feel that this lab underscores the skills necessary to be a scientist which I think also are essential to a student’s learning. And my reflection on whether I enjoyed the lesson also shows how teaching impacts me. Enjoyment came from students being engaged in a lesson demonstrating good attitudes towards that lesson. I recorded enjoyment during project work days, most labs in both units and during interesting presentations. I did not enjoy lessons where I presented material that I thought was not interesting and when students were off-task because they were not engaged.

Sub-question 2: What student attitudes are present during science inquiry lessons?

Ninth grade earth science students had a positive attitude during both units of study. The AR results indicate that student attitudes measured by the Student Questionnaire before the science inquiry unit were significantly different than student
attitudes measured after and the trend was that students’ attitudes decreased. However, the average Likert value numbers for the attitude groupings were all below neutral and towards agree. Students agreed that they liked school, they were interested in earth science, and they thought Earth Science class is fun. In the interview, ninth grade student attitudes were positively affected by socializing with friends and the learning aspects that they enjoyed. Students are also affected negatively by pressure to do well, bad behavior of some other students, and homework after school, though they still had a lot of positive things to say. The interviews showed that they liked the science inquiry unit in astronomy because it had big ideas and lots of unknown. Students liked to do lab activities and projects. They liked to be hands on and be able to see the phenomenon visually. They did not like taking notes because they thought it was boring and felt that I went to fast so they were not able to fully understand. I took this in account and have tried to work on the pace of notes. They may not have liked taking notes but many of those interviewed thought it helped them learn. And in the interview, all students had fun in science because of the labs; one student specifically said they liked open inquiry labs. Supporting the good attitudes found from the interview, I perceived that student attitudes improved in my daily reflections during the treatment group. The best attitudes I recorded during the treatment unit reflect that students liked to do open-ended inquiry labs, liked presentation with demonstrations and during project work time. Notably, they had fun in the open inquiry Impact Crater lab. During the non-treatment group my Teacher Journal Reflections show that students enjoyed similar activities such as cookbook lab, presentations and demonstrations. I thought the most fun that they had
was crushing cans because of the exciting natural phenomenon. So yes, the trend from the survey went down, though I think student attitudes were positive in each unit. I cannot say if they like one teaching strategy over the other from my results. I think if students are involved in the doing of science, then they will be interested and enjoy the experience. Students also like to engage in science information during presentation and demonstrations. I learned that presenting during the explain phase of the 5E is appreciated by the students, which was contrary to what I thought prior to conducting this AR. Additionally, I learned that students like to work with others and they also prefer to choose their own partners. This theme was discussed in the essential question because student engagement also increased with partner work. Working with others is an important skill that I did not assess in sub-question 3 but I feel that it is important to learn how to effectively collaborate with others.

**Sub-question 3: How are students’ science inquiry skills affected by this treatment?**

The treatment improved students’ science inquiry skills of Asking Questions, Planning and Carrying Investigations, Analyzing and Interpreting Data, and Obtaining, Evaluating and Communicating Information. The normalized gains from pre-assessment to post-assessment was 58.1 percentage points. The students improved in all four areas in the open-ended inquiry style of lab. The students completed two labs that were open-ended inquiry, one of which was used as the pre-assessment. During the second lab, “Period of Orbit,” I provided a lot of critique in all areas, which improved student skills. The lowest student-scored practice was Obtaining, Evaluating, and Communicating Information in which only 24% scored a 4 out of 4. The student confidence in this skill
was 47% which indicated that they were overly confident in their abilities. Students were expected to support their claim with evidence and provide reasoning for how this works. Students did well on writing a claim but struggled in writing supporting evidence and reasoning. This is new skill to earth science students and they were overconfident because they were unaware of the higher expectations. Open-ended inquiry labs are an excellent method for teaching science inquiry skills. Though I think open-ended inquiry does not teach content learning targets as well as cookbook labs, it does foster better science skills and helps develop better future scientists. This finding supports National Resource Council’s goal (2005), which is preparing students for college, career and citizenship by understanding how scientists do science.

VALUE

The purpose of my research was to see if teaching science inquiry to earth science students increases student engagement and students’ conceptual understanding. I learned much from this study, and I plan to implement the information learned into my daily lessons and other units of study. I found that teaching through science inquiry increases students’ conceptual understanding. I believe it is because the 5E Learning Cycle provides a framework for students to delve into the assigned learning targets because of the different learning strategies implemented in each phase. I will use this strategy for my other units of study when applicable. The aspect that makes the 5E Learning Cycle hard to implement is the amount of time it requires. Traditional lessons can cover one learning target a day while the 5E instructional teaching strategy may take two to three days to cover a learning target. Conceptual learning may increase, but the amount of
material covered will decrease, even though, I personally would rather see a higher level of understanding in my students rather than more content covered.

I learned a lot about student engagement through my AR. Students are engaged when they are interested in the material and when they are doing science. Activities in both types of units engaged students. I found it interesting how engaged students were to presentations to which I thought they would be less engaged. I will continue to present material to students because students think it increases their conceptual understanding, and presentations connect information for students before they go on to research or conduct labs. I will focus on making my presentation interesting and including demonstrations that get a “wow” factor from the students. Students were also engaged in open-ended inquiry labs so I will try to implement at least one of these a quarter where students will develop their own research question. NGSS emphasizes the importance of these skills demonstrated in these labs in the Science and Engineering practices and I found that students increased their science through these types of labs. Open-ended inquiry labs are difficult to teach a specific concept because students are driving their own questions. Additionally, student data varies, and students have a challenging time relating their research to the natural world. Whereas a traditional lab is easier to relate because teachers can focus the learning. Even though open-ended inquiry has its shortcomings, I feel that the skills taught by these labs are important to learn. Students also had high engagement in labs that demonstrated natural phenomenon so I will continue administering both science inquiry labs and traditional labs that have these components.
Another highlight from this project was what I learned about student attitudes and engagement with respect to independent research. Independent research allows students to study an area that interests them and to really gain a better understanding of a specific area. Students showed a high level of engagement and positive attitudes when completing independent projects. If students get engaged in their learning, then their attitude towards science improves, which may lead to more engagement in other aspects of class such as presentations and elaborating activities. Furthermore, I had a high level of enjoyment watching students present their hard work. They had a lot of pride in what they had accomplished. A drawback to independent research, like the 5E Learning Cycle, is that it takes time away from other curriculum, but I nonetheless will try to implement independent research projects at least once per semester.

This research also showed that students think they learn better working with others and their engagement increases during group work. I will continue to have students do group work in labs and projects. I think that it is very beneficial to have this discourse with others to understand a concept. While students preferred choosing their own partner, I think it should be alternated with the teacher choosing partners and groups. I find that some students work well with their chosen partner though some students exhibit more off-task behavior. Also, I think it is important to work with people you do not know as well so you can meet new people and be exposed to different perspectives. It is more like the real world of jobs where you do not generally get to choose your work colleagues. In addition to doing partner and group work, I also want to increase the
amount of discourse during presentations and smaller activities. I want students to share their ideas to others to make sure they are understanding the concept prior to assessments.

The major change I will make in my lesson planning is to incorporate more misconception probes and create more opportunities for discourse and sense-making strategies to help students change the construction of their preconceptions. I found that students had a tough time changing their constructed view of the natural world. Misconception probes are a tool that are found to work for this problem. Additionally, I plan on having students complete more One-sentence Summaries and Muddiest Point to be able to find out more often what their constructed view is. I plan on addressing their muddiest point the following day in hopes of improving conceptual understanding.

Material must be taught a mile deep and an inch wide. Because I believe my research can be applied to all science disciplines. I plan to share my work with my science colleagues. I plan to rework my other units and refocus my earth science Professional Learning Community to use more of these teaching strategies. Our district adopted NGSS and this will change our Professional Learning Communities scope and sequence. Because NGSS Science and Engineering Practices are emphasized within our district, I have been reassured that science inquiry skills are important. I would like to focus my next area of research on the other NGSS Science and Engineering Practices. I have researched four of the eight and I believe my teaching and future students would benefit from investigating the effects of the other four.
REFERENCES CITED


APPENDICES
APPENDIX A

MONTANA STATE UNIVERSITY

INSTITUTIONAL REVIEW BOARD

EXEMPTION OF REVIEW
MEMORANDUM

TO: Tyler Hollow and Walt Woolbaugh
FROM: Mark Quinn, Chair, Institutional Review Board for the Protection of Human Subjects
DATE: November 17, 2017
RE: “How Does Teaching Scientific Inquiry Through the 5E Learning Cycle and Other Strategies Effect 9th Grade Earth Science Student’s Engagement and Their Conceptual Understanding?” [TH111717-EX]

The above research, described in your submission of November 16, 2017, 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 B

HELENA HIGH SCHOOL

ADMINISTRATIVE APPROVAL AND

EXEMPTION REGARDING INFORMED CONSENT
HELENA HIGH SCHOOL
1300 BILLINGS AVE.
HELENA, MONTANA 59601-3981

Administrator Approval

I, Steve Thennis, Principal of Helena High School, verify that I approve of the classroom research conducted by Tyler Hollow.

Signed Name, Title of Position

Printed Name

(Date)

Administrator Exemption Regarding Informed Consent

I, Steve Thennis, Principal of Helena High School, verify that the classroom research conducted by Tyler Hollow is in accordance with established or commonly accepted educational settings involving normal educational practices and that I approve the project. To maintain the established culture of our school and not cause disruption to our school climate, I have granted an exemption to Tyler Hollow regarding informed consent.

Signed Name, Title of Position

Printed Name

(Date)
APPENDIX C

CURRICULUM OF NON-TREATMENT UNIT AND TREATMENT UNIT
<table>
<thead>
<tr>
<th>Day</th>
<th>Activity</th>
<th>Assessment</th>
<th>Learning Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/15/2017</td>
<td>Bell Ringer Humidity Lab</td>
<td>Lab worksheet</td>
<td>I can understand and calculate relative humidity.</td>
</tr>
<tr>
<td>12/18/2017</td>
<td>Bell Ringer Presentation on Humidity</td>
<td>None</td>
<td>I can understand and calculate relative humidity. I can distinguish between dew point and relative humidity</td>
</tr>
<tr>
<td>12/19-12/20/2017</td>
<td>Bell Ringer Relative and Dew Point Lab</td>
<td>Lab Write-up</td>
<td>I can understand and calculate relative humidity. I can distinguish between dew point and relative humidity</td>
</tr>
<tr>
<td>12/21/2017</td>
<td>Quiz- Humidity Concept Map Presentation on Clouds</td>
<td>Quiz</td>
<td>I can model a cloud and know the conditions that cause cloud formation.</td>
</tr>
<tr>
<td>12/22/2017</td>
<td>Film – Unchained Goddess</td>
<td>None</td>
<td>NA</td>
</tr>
<tr>
<td>1/2/2018</td>
<td>Bell Ringer Cloud in the Bottle Lab</td>
<td>Lab worksheet</td>
<td>I can model a cloud and know the conditions that cause cloud formation.</td>
</tr>
<tr>
<td>1/3/2018</td>
<td>Bell Ringer Presentation on High and Low pressure</td>
<td>One Sentence Summary. Muddiest Point</td>
<td>I can understand high and low air pressure and how pressure difference influence weather.</td>
</tr>
<tr>
<td>1/4/2018</td>
<td>Bell Ringer Can crushing activity Air Pressure Worksheet</td>
<td>Activity Worksheet</td>
<td>I can understand high and low air pressure and how pressure difference influence weather.</td>
</tr>
<tr>
<td>1/5/2018</td>
<td>Bell Ringer Presentation of Local and global wind. Coriolis Effect Lab</td>
<td>Lab write-up</td>
<td>I can understand the Coriolis Effect and how it effects regional and global winds. I can understand the relationship between temperature, pressure and winds.</td>
</tr>
<tr>
<td>1/8/2017</td>
<td>Bell Ringer Coriolis effect video. Presentation on Air masses and fronts</td>
<td>None</td>
<td>I can understand the Coriolis Effect and how it effects regional and global winds. I can evaluate severe storms and conditions that cause them.</td>
</tr>
<tr>
<td>1/9/2018</td>
<td>Bell Ringer Air masses and front station activity</td>
<td>Station activity write-up</td>
<td>I can evaluate severe storms and conditions that cause them.</td>
</tr>
<tr>
<td>1/10/2018</td>
<td>Bell ringer Monsoons reading and annotations. Monsoons model</td>
<td>Model</td>
<td>I can evaluate severe storms and conditions that cause them.</td>
</tr>
<tr>
<td>1/11/2018</td>
<td>Kahoot Test Review</td>
<td>Kahoot Test Review</td>
<td>NA</td>
</tr>
<tr>
<td>1/14/2018</td>
<td>Weather and Storms Test (Post-assessment) Student Questionnaire</td>
<td>Test</td>
<td>NA</td>
</tr>
<tr>
<td>Treatment Unit – Astronomy Science Inquiry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/22/2018</td>
<td>Bell Ringer Misconception Probe Apple and Gravity.</td>
<td>Misconception probe</td>
<td>I can understand the concept of gravity.</td>
</tr>
<tr>
<td>Date</td>
<td>Activity</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>------------------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>1/23/2018</td>
<td>Bell Ringer Impact Crater Lab</td>
<td>Lab write-up I can plan and carry out an experiment.</td>
<td></td>
</tr>
<tr>
<td>1/24/2018</td>
<td>Bell Ringer Pre-test Astronomy Finish Impact Crater Lab</td>
<td>Pre-assessment Lab write-up I can plan and carry out an experiment.</td>
<td></td>
</tr>
<tr>
<td>1/25/2018</td>
<td>Bell Ringer Engage Film “Expanding Universe”</td>
<td>Film Guide I can understand the evidence that supports the Big Bang.</td>
<td></td>
</tr>
<tr>
<td>1/26/2018</td>
<td>Pre-assessment Moon Phases Misconception Probe. Lunar Hats Lab Presentation on Moon Phases</td>
<td>Lab worksheet Misconception Probe I can model the phases of the moon.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post-assessment Moon Phases Misconception Probe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/29/2018</td>
<td>Bell Ringer Explore – Doppler Effect Lab</td>
<td>Lab write-up I can explain the doppler shift and relate it to celestial bodies.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I can understand the evidence that supports the Big Bang.</td>
<td></td>
</tr>
<tr>
<td>1/30/2018</td>
<td>Bell Ringer Explain-Presentation on Big Bang</td>
<td>None I can analyze the scientific theory of the Big Bang.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I can understand the evidence that supports the Big Bang.</td>
<td></td>
</tr>
<tr>
<td>1/31/2018</td>
<td>Bell Ringer Explain- Reading “How do Scientists measure the age of our universe?” Annotate</td>
<td>Annotations in reading I can understand the evidence that supports the Big Bang.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2/1/2018</td>
<td>Bell Ringer Two column notes and summary of reading “How do Scientists measure the age of our universe?” Annotate</td>
<td>Summary of reading I can understand the evidence that supports the Big Bang.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2/2/2018</td>
<td>Elaborate- Newscast on Big Bang</td>
<td>Newscast video I can analyze the scientific theory of the Big Bang.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I can understand the evidence that supports the Big Bang.</td>
<td></td>
</tr>
<tr>
<td>2/5/2018</td>
<td>Evaluate -Big Bang Concept Map Quiz Engage – Momentum and gravity phenomenon</td>
<td>Concept Map I can understand the Kepler’s three laws of planetary motion.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I can investigate the effect of planetary size and distance from the sun on period of orbit.</td>
<td></td>
</tr>
<tr>
<td>2/6/2018</td>
<td>Bell Ringer Explore – Period of Orbit Lab</td>
<td>Lab write-up I can understand the Kepler’s three laws of planetary motion.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I can investigate the effect of planetary size and distance from the sun on period of orbit.</td>
<td></td>
</tr>
<tr>
<td>2/7/2018</td>
<td>Bell Ringer Explore -Finish Period of Orbit Lab</td>
<td>Lab write-up I can understand the Kepler’s three laws of planetary motion.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I can investigate the effect of planetary size and distance from the sun on period of orbit.</td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>Bell Ringer</td>
<td>Activity</td>
<td>Textbook questions</td>
</tr>
<tr>
<td>------------</td>
<td>-------------</td>
<td>----------</td>
<td>--------------------</td>
</tr>
<tr>
<td>2/8/2018</td>
<td>Explain – Present findings from lab. Reading from Earth Science Textbook with questions.</td>
<td>Textbook questions</td>
<td>I can understand the Kepler’s three laws of planetary motion. I can investigate the effect of planetary size and distance from the sun on period of orbit.</td>
</tr>
<tr>
<td>2/12/2018</td>
<td>Explain – Presentation on Early Astronomy (Kepler’s Laws)</td>
<td>None</td>
<td>I can understand the Kepler’s three laws of planetary motion. I can investigate the effect of planetary size and distance from the sun on period of orbit.</td>
</tr>
<tr>
<td>2/13/2018</td>
<td>Elaborate – Kepler’s 2nd and 3rd Law Activities</td>
<td>Activity worksheet</td>
<td>I can understand the Kepler’s three laws of planetary motion. I can investigate the effect of planetary size and distance from the sun on period of orbit.</td>
</tr>
<tr>
<td>2/14/2018</td>
<td>Elaborate - Finish Kepler’s Third Law Evaluate - Solar System Project</td>
<td>Activity Worksheet Solar System Project</td>
<td>I can understand the Kepler’s three laws of planetary motion. I can investigate the effect of planetary size and distance from the sun on period of orbit.</td>
</tr>
<tr>
<td>2/15/2018</td>
<td>Film – “Failure is Not an Option.”</td>
<td>Film Guide</td>
<td>NA</td>
</tr>
<tr>
<td>2/16/2018</td>
<td>Engage – Misconception Probe “What happens to stars when they die?” Explore – Life cycle of stars research.</td>
<td>Life cycle of stars research activity.</td>
<td>I can model nuclear fusion. I can model the life cycle of the star. I can analyze the H-R diagram to identify where the star is in its life cycle.</td>
</tr>
<tr>
<td>2/20/2018</td>
<td>Misconception probe “What is the Sun made up of? Explore - Finish Life cycle of stars research.</td>
<td>Misconception Probe Life cycle of stars research activity.</td>
<td>I can model the life cycle of the star. I can analyze the H-R diagram to identify where the star is in its life cycle.</td>
</tr>
<tr>
<td>2/21/2018</td>
<td>Explain - Presentation on the Sun and nuclear fusion.</td>
<td>One-sentence summary Muddiest Point</td>
<td>I can model nuclear fusion.</td>
</tr>
<tr>
<td>2/22/2018</td>
<td>Elaborate – Nuclear Fusion modeling activity</td>
<td>Model</td>
<td>I can model nuclear fusion.</td>
</tr>
<tr>
<td>2/23/2018</td>
<td>Evaluate – Concept map quiz on nuclear fusion. Engage – Spectrometers and flashlights</td>
<td>Concept map quiz</td>
<td>I can model nuclear fusion.</td>
</tr>
<tr>
<td>2/26/2018</td>
<td>Explore-Spectroscopy activity Explain – Presentation on the study of stars and life cycle of stars</td>
<td>One-sentence summary Muddiest Point</td>
<td>I can analyze the H-R diagram to identify where the star is in its life cycle. I can explain the doppler shift and relate it to celestial bodies.</td>
</tr>
<tr>
<td>2/27/2018</td>
<td>Elaborate – Hertzsprung Russel graphing activity</td>
<td>Graphing activity</td>
<td>I can analyze the H-R diagram to identify where the star is in its life cycle.</td>
</tr>
<tr>
<td>2/28/2018</td>
<td>Evaluate-Finish solar system project</td>
<td>Solar system project</td>
<td>I can model the life cycle of the star. I can analyze the H-R diagram to identify where the star is in its life cycle.</td>
</tr>
<tr>
<td>Date</td>
<td>Activity</td>
<td>Description</td>
<td>Notes</td>
</tr>
<tr>
<td>------------</td>
<td>--------------------------------------------------------------------------</td>
<td>--------------------------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>3/1/2018</td>
<td>Bell Ringer</td>
<td>Kahoot Astronomy Test review</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kahoot test review</td>
<td></td>
</tr>
<tr>
<td>3/2/2018</td>
<td>Astronomy Summative Assessment (Post-assessment)</td>
<td>Post-assessment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Science Skill Survey</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Student Questionnaire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/5/2018 –</td>
<td>Science circus project of student choosing</td>
<td>Presentation of student project.</td>
<td>NA</td>
</tr>
<tr>
<td>3/9/2018</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX D

STUDENT SCIENCE INQUIRY SURVEY
The Student Science Inquiry Survey

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

Directions: place a check in the box the best fits your abilities for each Next Generation Science Standards Science and Engineering Practice Stage.

<table>
<thead>
<tr>
<th>Next Generation Science Standards Science and Engineering Practice Stage</th>
<th>I am very confident in my abilities</th>
<th>I am somewhat confident in my abilities</th>
<th>I am not confident in my abilities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Asking Questioning</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asking questions based on observations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Creating scientific investigation type of questions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ask questions that can be investigated within the classroom</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ask questions to determine relationships between independent and dependent variables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Planning and Carrying out investigations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brainstorming what to do and steps to take</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Writing a detailed procedure that is repeatable by someone else</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identifying independent variable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identifying dependent variable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identifying control group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identifying experimental group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Determining all tools and materials needed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagraming or sketching appropriate parts of the investigation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assuming leadership role</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Making constructive contributions to the group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gathering quantitative and qualitative data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Making accurate measurements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taking careful notes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Analyzing and interpreting data</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organizing data into charts and graphs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analyze graphs and other figures to find relationships</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analyze data to provide evidence for phenomena</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use statistics such as averages and percentages to analyze data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consider limitations of data analysis (e.g., experimental error), and/or seek to improve precision and accuracy of data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Obtaining, evaluating and communicating information</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Close read scientific literature to determine the key points and supporting details</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Support claim (conclusion) with evidence such as qualitative or quantitative data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Read appropriate sources and assess the credibility, accuracy, and possible bias.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communicate scientific information through writing or orally</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


APPENDIX E

INTERVIEW QUESTIONS
Interview Questions

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

1. Do you like school?
   Probe - What about school do you like or not like?

2. Do you find science in general interesting?
   Probe - What do you find interesting about science?
   Probe - Why do you not find science interesting?

3. Do you like science class?
   Probe – Why do you say that?

4. What are some activities we do in class that you like?
   Probe – Why did you like this activity?
   Probe – Did this activity also help you learn? How did this activity help you learn?

5. What are some activities that we do in science class you are the least comfortable with or do you like the least?
   Probe – What about this activity do you not like?

6. Do you feel you are able to successfully complete the activities we do in science class?
   Probe – Why do you say you that?
   Probe – How do you know if you are successful or not? Is this way okay for you?

7. Do you feel like you are learning in science class?
   Probe - What activities do we do that help you learn?
   Probe - What activities are the hardest for you?

8. Do you feel engaged in science class?
   Probe – What activities are the most engaging? The least?

9. Do you like to design your own experiment, or would you rather have me provide you with a procedure?
   Probe - Which type do you learn better?

10. Is there anything else you would like me to know regarding this science class?
APPENDIX F

STUDENT QUESTIONNAIRE
Student Questionnaire

Participation in this research is voluntary and participation or non-participation will not effect a student’s grade or class standing in any way.

Directions: This survey was created to gain a better understanding of students’ attitude towards earth science and engagement in the class. Rate the following questions with 1. Strongly Agree, 2. Agree 3. Undecided (neutral) 4. Disagree 5. Strongly disagree

Attitude

1. I really like school.
2. Earth science is very interesting to me.
3. Earth science class is fun.
4. In general, I have a good feeling toward earth science.
5. I enjoy figuring out answers to earth science questions.
6. I feel comfortable to ask questions or share my opinion in class.
7. I feel welcome and comfortable in this class.
8. I enjoy working with lab partners and in small groups.
9. Earth science is easy for me to learn and do well in the class.
10. I think the skills and content I learn in earth science are important to my life after high school.

Engagement

11. When I am answering an earth science question, I find it difficult to put what I know into my own words.
12. If I get stuck on answering an earth science question on my first try, I usually try to figure out a different way that works until I get it.
13. Learning earth science changes my ideas about how the natural world works.
14. Working with lab partners and in small groups helps me learn the concept.
15. Choosing my own lab partners and small groups improve my ability to learn.
16. I am confident that I can do well in earth science class.
17. I am putting forth a lot of energy to do well in earth science class.

18. I listen carefully in class.

19. I study earth science on a regular basis.

20. I work hard to understand the concept because I want to learn earth science.

**Teaching Methods**

21. For me, earth science is primarily about learning known facts as opposed to investigating the unknown.

22. I am more interested in labs when I write my own research questions and hypothesis.

23. I like labs more when I write my own directions instead of following directions already written for the lab.

24. I learn more when I write my own directions instead of following directions already written.

25. I would rather research science concepts than have the teacher present the concept by notes.

26. I learn the concept better when I research science concepts on my own.

27. I learn the concept better when the teacher presents the concept by notes.

28. I learn better when I discuss the information with my group.

29. I am open to learning new information about earth science even if it goes against my beliefs.

30. I like to ask questions about the natural world.

**Open-ended questions**

1. Would you rather learn a concept by taking notes from the teacher or would you rather learn the concept on your own through research? Explain

2. Do you like labs that you design or do you like labs better when the teacher provides you the directions? Explain

3. How do you learn a concept the best? Explain

4. Do you like coming to earth science class? Why or why not?

5. Do you think learning earth science is important for your future? Why or why not?
APPENDIX G

RESPONSES TO STUDENT INTERVIEW QUESTIONS
## Student interview questions responses

<table>
<thead>
<tr>
<th>Question and probe</th>
<th>Student responses</th>
<th>Trends</th>
</tr>
</thead>
</table>
2. Yes, like elective options, dislike homework.  
3. Yes, like socializing with teacher and friends, new opportunity, dislike pressure to do well.  
4. Yes like history, dislike kids who smoke.  
5. Yes, like band, dislike gym and math.  
6. Yes, like social aspects and dislike ways teacher teach.  
7. No, like learning aspects, dislike environment and peers.  
8. Yes, like social side and freedom, dislike homework.  
9. Yes, like to hang out with friends and get an education, dislike homework.       | All but one liked school.  
Liked: the social aspect; freedom; electives; and education.  
Disliked: homework; bad behavior.                                                                                                     |
2. Yes interested in working in field. Agree with number 1. Astronomy, because it is outside the box.  
3. Yes, interested in working in field. Geology. Astronomy because it is big thinking, like the Big Bang.  
4. Yes, no answer.  
5. Some, not super, but not boring. Like to learn about why stuff works, fun to know it. Astronomy, I do not know why.  
7. Yes, interested in how things work. Astronomy and universe is interesting.  
8. Yes, interested to know anything and everything. Oceanography, ocean is interesting and rock and geology.  
9. Some units, interested in astronomy, space is cool to learn about. Labs are interesting. | Seven students liked science and two liked some of it.  
Found interesting: open-ended and big thinking; astronomy and specifically the Big Bang; how stuff works.  
Subjects liked: Six liked astronomy, others mentioned were atmosphere, geology twice and climate change. |
| 3. What are some activities we do in class that you like? Probe – Why did you like this activity? Probe – Did this activity also help you learn? How did this activity help you learn? | 1. Labs, I like to see it visually. Yes due to visual.  
2. Labs, like it better than notes. Yes, see it and hands on.  
3. Labs that are open-ended, interesting. Yes because it is visual.  
4. Bring items out to show, demonstrations. Yes it helped me take it in.  
5. Projects and labs, because doing something hands-on. Notes work better, though labs are more fun.  
6. Creating labs, more interesting because I want to find answer. Yes it helped me learn.  
7. Creating labs, because they help me learn. Yes it helped me learn.  
8. Labs and working with partners on two-day experiments. Ask questions that I want to know. Yes it helped me learn.  
9. Group work and labs because it is good to have another perspective from other person. Yes it helped me learn because of the discussion. | All nine students liked labs, while one liked demonstration and another liked projects.  
Why labs: student liked the hands-on component, they thought labs are more fun. These strategies helped them learn because it was visual. Three preferred creating their own labs because it helped them learn.  
Student 5 thought notes worked better for them in learning.  
Student 9 liked labs because of working with others and discussion had. |
| 4. What are some activities we do in class that you dislike? Probe – Why did you dislike this activity? | 1. Hydrology was boring in content.  
2. Notes, need smaller amounts.  
3. Large scale notes and hydrology. Need smaller amounts.  
4. Not much, no answer  
5. Do not like labs that I create by myself. Easy to get lost, easier with instructions. | Seven students did not like notes. Some said because teacher goes to fast and hard to keep up, prefer smaller chunks. |
| Probe – Did this activity also help you learn? How did this activity help you learn? | 6. Notes too fast, need to write and then pay attention.  
7. Notes too fast, need to write and then pay attention.  
8. Don’t like notes, need more time to listen and write.  
9. Notes, hard to keep up because I write in cursive. | Seven student thought science was fun while two said that sometimes science is fun.  
Labs and science circus projects were examples mentioned. |
| --- | --- | --- |
| 5. Do you think science class is fun. Provide an example. | 1. Yes, learning.  
2. Yes, labs.  
3. Yes, moving and outside.  
4. Yes, crafting  
5. Sometimes, science circus presentation.  
6. Yes, create own labs.  
7. Yes, science circus project.  
8. Yes, building models and labs.  
9. Sometimes, talking about stuff is boring, while doing stuff is interesting. | All nine students are engaged in science class. Two students thought astronomy was most engaging. Student six thought notes were most engaging. |
| 6. Do you feel engaged in science class? Probe – What activities are the most engaging? The least? | 1. Yes, astronomy is fun to learn.  
2. Yes,  
3. Yes, astronomy.  
4. Yes, hard questions, no answer to question.  
5. Yes, notes, I don’t know the least.  
6. Yes, notes are the most engaging.  
7. Yes, hands-on.  
8. Yes, hands-on.  
9. Yes, labs | Labs |
| 7. Do you feel more engaged in labs or other types of work? Why | 1. Labs  
2. Labs  
3. Labs  
4. Labs  
5. Equal engagement in all activities.  
6-9 did not answer do to a repeat in the answer. | Three students liked both types evenly. Four thought designing own experiment was better. Two students preferred provided procedure. |
| 8. Do you like labs that you design your own experiment or would you rather have me provide you with a procedure? | 1. Both types, fun prepared and do it yourself.  
2. I like both types.  
3. Like both types, create my own, more freedom.  
4. Own experiment.  
5. Provide with own procedure.  
6. Design.  
7. Design.  
8. Design  
9. Provide with procedure, then the teacher knows the answer instead of getting wrong data. | Four said depends on the on-task behavior from partners. Four said group work.  
Seven said they prefer to pick their own partner, while two just wanted good partners that will work. |
| 9. Do you feel engaged in learning in group work or individual work? Probe – Do you like to pick your partner or have one chosen for you? | 1. Depends, if group is on task. Pick your partner choose someone that will work.  
2. Depends on who you work with, bad if you have someone that is not working. Pick partner.  
3. Depends if group is on task. Pick your partner.  
4. Individual work, because no one likes to work with me. Doesn’t matter, able to work with them.  
5. Depends on who is in the group. Pick partner.  
6. Group work, pick partner.  
7. Group work, pick partner.  
8. Group work, pick partner.  
9. Group work, pick partner. | Students don’t really seem to like notes, but they think they are useful for studying and helps them learn. |
2. I don’t care, it is really easy, can look back on it for quizzes, definitely helpful.  
3. OK, but small chunks. Helps us solidify information.  
4. Used to it, can help.  
5. Same as number 2. Yes.  
6. Yes, helps me review for studying and yes to learning.  
7. Yes, good listening skills and yes for learning.  
8. No, missing the slide or teacher talking and no for learning due to this. | |
<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
</tr>
</thead>
</table>
| 11. What helps you learn a concept or information? Probe – Provide an example. | 1. Seeing it visually, like watching the video, long or short.  
2. Notes or labs, notes help quite a bit.  
3. Seeing it, like modeling the ozone.  
4. Visually, museums, not a lot of words.  
5. Notes, on the board I get it.  
6. Teacher talks to you individually.  
7. Talks to you individually.  
8. Explain it and do a demonstration.  
9. By doing, I am ADD and I get fidgety and space off. Example was the lunar craters and collect data by yourself.  

Student like to see the concept visually.  
Some liked to be hands-on.  
Some liked to have it explained and a demonstration.  
Two wanted individual attention.  |
| 12. Does your brain ever hurt because you are thinking so hard? Why or why not? | 1. Ask, did not hurt with Big Bang.  
2. No, big bang. I referred back to my notes.  
3. Ask if I don’t get it, open my mind.  
4. No I keep working towards it, and sleeping helps me learn it.  
5. No, Big Bang, I google it if I don’t get it.  
6. Yes, not getting done and being rushed.  
7. Yes, not getting done and being rushed.  
8. Yes, when I try to remember the answer.  
9. Yes, I try to calm down and ask the person next to me.  

Students didn’t really have that disequilibrium feeling that I was looking for. Some hurt due to being rushed while others did not hurt when they didn’t know an answer they just worked through it. |
APPENDIX H

TEACHER JOURNAL REFLECTIONS
Teacher Journal Reflections

Note: Researcher reflected on these eight questions. Not all eight questions were answered daily, rather only those that I deemed appropriate.

1. How is my energy level at the end of the day?
2. Was I able to show my passion of science through this lesson?
3. Did I enjoy the lesson today?
4. What was a memorable student to teacher interactions?
5. How did students seem to react to each lesson?
6. What went well?
7. What improvements can I make?
8. Did I create relevancy for my students?