INCREASING STUDENT ACHIEVEMENT IN SCIENCE THROUGH THE USE OF
THE 5 E INSTRUCTIONAL METHOD

by

Kyle Mark Casper

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

of

Master of Science

in

Science Education

MONTANA STATE UNIVERSITY
Bozeman, Montana

July 2015
# TABLE OF CONTENTS

1. INTRODUCTION ................................................................. 1

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

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

4. DATA AND ANALYSIS .......................................................... 13

5. INTERPRETATION AND CONCLUSION .................................... 20

6. VALUE ................................................................................ 21

REFERENCES CITED .................................................................. 23

APPENDICES ........................................................................... 26

   APPENDIX A Science Attitude Survey ...................................... 27
   APPENDIX B Astronomy Pre and Post Assessment .................... 29
   APPENDIX C Matter Pre and Post Assessment ......................... 31
   APPENDIX D Student Interview Questions ............................... 33
   APPENDIX E Teacher Reflection Questions .............................. 35
   APPENDIX F IRB Approval .................................................... 37
LIST OF TABLES

1. Data Triangulation Matrix ................................................................. 13
FUTURE LIST OF FIGURES

1. Zebrafish Embryo .................................................................2
2. Zebrafish Larvae .................................................................2
3. Adult Zebrafish .................................................................3
4. Zebrafish Habitat in Lincoln ................................................3
5. Science Attitude Survey Results Item 1 ..................................14
6. Science Attitude Survey Results Item 2 ..................................15
7. Science Attitude Survey Results Item 4 ..................................16
8. Science Attitude Survey Results Item 5 ..................................17
9. Science Attitude Survey Results Item 7 ..................................18
10. Comparison of Astronomy Pre/Post-assessment ....................19
11. Comparison of Matter Pre/Post-assessment ...........................19
ABSTRACT

Experts consider science inquiry as a best practice in science education. Inquiry instruction has a long history and is included in numerous versions of science education standards today. The purpose of this study is to determine the effect of 5 E learning cycle inquiry-based units on student attitudes and content acquisition in middle school science classes compared to direct instruction methods. All grade eight students in two sections of Earth science received the treatment, a 5 E learning cycle unit on matter (N=37). The 5 E treatment unit was administered following a unit on astronomy that used the traditional direct instruction methods of lecture, notes, chapter reading, and teacher directed activities for comparison.
INTRODUCTION AND BACKGROUND

Lincoln K-8 School serves approximately 500 students in Rochester, Minnesota. The school started as an alternative elementary school in 1975 and expanded from K-6 to K-8. Over the last five years, technology and science have emerged as the school’s unofficial focus. The school has a partnership with the Mayo Clinic of Rochester, MN called InSciEd Out. The goal of the program is to increase student engagement in science using zebrafish, which Mayo uses as a model organism. Lincoln is a district-wide option school with a waiting list and lottery system to enroll. Families choose to send their students to Lincoln and support the school by volunteering and fundraising. The student body is comprised of 18.6% free and reduced lunch compared to 37.2% for the state of Minnesota. Limited English Proficiency students are 3.6% of the group compared to 7.7% in the state (Lincoln K-8, 2014). In 2013, the eighth grade class at Lincoln had the highest percent of students proficient on the Minnesota Comprehensive Assessment test in science. Of the 31 students, 83.9% of the students were proficient compared to 47.9% in the Rochester Public School district. The group was in the 97.7 percentile for average score and ranked 11.5 in the state (LaBounty, 2014).

The InSciEd Out program is an interdisciplinary science education outreach program. Teachers and scientists create interdisciplinary modules using the 5 E learning cycle model. Each year the students participate in an interdisciplinary inquiry-based unit module on topics such as addiction, obesity, toxicity, and infectious disease. Zebrafish (Danio rerio) are a freshwater fish that are a non-mammalian vertebrate model organism used at the Mayo Clinic and by over a thousand laboratories around the world because of
its biological similarity to humans, and its advanced molecular genetics, and the knowledge of its genome sequence. The zebrafish embryo is transparent during development allowing researchers to track the regulation of gene expression (Mayo Clinic Zebrafish, 2015).

![Figure 1. Zebrafish embryo.](image)

![Figure 2. Zebrafish larvae.](image)

Zebrafish in education offer opportunities for using active and experiential approaches to learn developmental biology, genetics, neurobiology, and behavior for students in grade school through undergraduates. Zebrafish are cost effective, easy to
maintain, and reliable at producing large amounts of embryos when needed. There is a wide range of wild-type and mutant strains available (Hutson & Liang, 2009).

Figure 3. Adult zebrafish.

Figure 4. Zebrafish habitat at Lincoln.

Prior to my employment at Lincoln, the science curriculum included zebrafish modules, a science fair project, and a majority of the curriculum was textbook-based with direct instruction (C. Dornack, personal communication, April 7th, 2014). I believe the zebrafish modules and science fair projects are a great way to increase science inquiry skills and build student engagement in science. One of my goals is to increase the amount
of inquiry-based instruction the students receive throughout the year in eighth grade Earth science. My concern is the direct instruction practice has shown to be effective as evident in Lincoln’s high proficiency rate on Minnesota Comprehensive Assessment test in science but is not best practice. My challenge was to build in more inquiry activities beyond the zebrafish modules and science fair projects while monitoring student attitudes about science, because I want to know what students think about science and what students think about the way they learn science. Also, I want to maintain a high level of proficiency on the Minnesota Comprehensive Assessment test in science. This led to the creation of my focus statement: What are the effects of 5 E learning cycle inquiry-based units on middle school science classes? In addition, the following sub-questions will be researched.

1. What are the effects of 5 E inquiry-based units on student attitudes?
2. What are the effects of 5 E inquiry-based units on content acquisition in middle school science classes?

CONCEPTUAL FRAMEWORK

Inquiry is the fundamental principle of how modern science is conducted. Inquiry refers to the thinking processes that lead to the development of new knowledge in science. Doing science and the knowledge about the processes scientists use to develop knowledge is the nature of science. Inquiry is the ability to do science processes, the knowledge about the processes and an approach to teach this ability and knowledge to students (Flick & Lederman, 2006). Experts consider science inquiry a best practice in science education. Inquiry instruction has a long history and is included in numerous
versions of science education standards today.

Inquiry is not a passing fad in education. John Dewey (1916), one of the first proponents of inquiry learning, said science learning must include the process of science and not just the information. Dewey stated that present methods, referring to a traditional lecture classroom, put the cart before the horse. Dewey’s horse represents the process of science inquiry pulling the cart of science content.

After the launch of Sputnik by the Soviet Union in 1957, the U.S. began to overhaul science education with science inquiry at the forefront of the initiative (Frelindich, 1998). The National Science Education Standards and the Benchmarks for Science Literacy hold inquiry-based instruction as the central method of instruction. Both sources defined inquiry as the acts scientists perform, an approach to teaching, and as the approach to learning science (American Association for the Advancement of Science, 1993; NRC 1996). The standards addressed the need for integrating science inquiry and content by identifying what students should know and be able to do (Llewellyn 2007).

In 2000, the National Science Teachers Association (NSTA) recommended all science teachers embrace scientific inquiry. NSTA (2004) has made it a goal to help educators make inquiry the centerpiece of the science classroom in order to ensure that students develop a deep understanding of science and scientific inquiry.

The Exploratorium in San Francisco is a science museum and professional development center for inquiry-based learning. The Exploratorium described inquiry as an approach to learning that involves exploring the natural and material world that leads to asking questions and making discoveries. Inquiry in science education should mirror
the process of real science. Inquiry is driven by the learner’s curiosity, wonder, interest or passion to understand an observation or solve a problem. It begins when the learner notices something of interest that creates a question and moves to take action through observing, making predictions, testing hypotheses and creating theories and building conceptual models. This is a cyclical process unique to the individual. As the process continues, deeper interaction with and understanding of science are possible. Resources and experts are consulted along the way. Meaning from the inquiry process is achieved through reflection, conversations and comparison of findings with others. The interpretation of data and the application of new conceptions to other contexts help the learner construct new mental frameworks of the world. The teacher is a facilitator for the learner’s process of discovery and creating understanding of the world (Exploratorium, 1998).

The learning cycle is one of the most popular models for inquiry instruction. Atkin and Karplus first proposed this model in 1962. The learning cycle had three phases of instruction. The exploration phase provides students with experiences to investigate. The concept introduction phase allows students to build ideas through interactions with peers, teachers, and texts. The third phase of concept application asks students to use these science ideas to solve new problems (Karplus & Thier, 1967).

The Biological Science Curriculum Study (BSCS) 5 E Instructional Model is based on the Karplus and Thier version (Bybee et al., 2006). Llewellyn (2007) explained the five stages of the learning cycle allow students to move from concrete experiences to the development of understanding to the application of principles. The first stage of the 5
E Instructional Model is called the *engagement* stage. This is where the teacher states the purpose of the lesson, the lesson topic, and learning expectations. An essential question can be introduced at this phase to ensure students know what they should know or be able to at the end of this phase. Demonstrations and discrepant events engage curiosity and set the stage for learning. During the engagement stage, teachers are able to assess prior knowledge and misconceptions.

The *exploration* stage provides opportunities for the student to actively engage in inquiry. Students explore, question, develop statements to test, and work without direct instruction. They collect data and evidence, record and organize information, share observations, and work in collaborative groups. This phase is hands-on learning and allows for differentiation in a diverse classroom. Group roles can be assigned with classroom management in mind or chosen by students based on strengths and interests (Llewellyn, 2007).

The third stage, called the *explanation* stage, has the teacher act as facilitator of data and evidence processing for the students. A lecture may be appropriate during this phase to explain scientific concepts associated with the exploration. Vocabulary is introduced to provide a common language for the class. The teacher uses students’ experiences to address concepts and misconceptions (Llewellyn, 2007).

The *elaboration or extension* stage is when the teacher extends and applies the evidence to a new and real-world situation. This helps to reinforce the concept and allows students to make generalizations. The elaboration stage can be an opportunity to investigate the questions generated from the engagement stage or provide an opportunity
for open-ended inquiry (Llewellyn, 2007).

The final stage is the *evaluation* stage. The teacher brings closure to the lesson or unit through helping students summarize the relationship between variables, posing higher-order and critical thinking questions to support students in making judgments about their work. During this phase, the teacher provides a way for students to assess their learning which could include multiple choice items, extended-response questions, essays, authentic tasks, portfolios, rubrics, monitoring charts, concept maps, and student self-assessment (Llewellyn, 2007).

The National Research Council (NRC) recommendation in A Science Framework for K-12 Science Education for the Next Generation Science Standards (NGSS) is to include inquiry within content standards. In this way, the NGSS differs from all previous standard documents. The NRC expects students will engage in inquiry practices and not merely learn about them. Since inquiry has been interpreted in many different ways throughout the science education community, the NRC (2012) recommends not using the term inquiry. Instead it specifies which practices of science and engineering to use within the content standard. The eight practices of science and engineering that the NRC identifies as essential for all students to learn and describes in detail are:

1. Asking questions (for science) and defining problems (for engineering).
2. Developing and using models.
3. Planning and carrying out investigations.
4. Analyzing and interpreting data.
5. Using mathematics and computational thinking.
6. Constructing explanations (for science) and designing solutions (for engineering).

7. Engaging in argument from evidence.

8. Obtaining, evaluating, and communicating information.

METHODOLOGY

All grade eight students in two sections of Earth science received the treatment, a 5 E learning cycle unit on matter ($N=37$). There are 18 boys and 19 girls in the 8th grade. The 5 E treatment unit was administered following a unit on astronomy that used the traditional direct instruction methods of lecture, notes, chapter reading, and teacher directed activities for comparison. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix A).

The non-treatment astronomy unit lasted three weeks. The lectures were given using a PowerPoint presentation. Each lecture started with a review or focus question and a description the learning targets of that day. This was used to review and engage prior knowledge. The students took notes in their notebooks and made drawings when applicable. Modeling and demonstrations were also used to engage students. Students were periodically given questions as homework to review and apply the content from the learning target. During the non-treatment unit, the students were limited to few group activities to keep them in a teacher-centered style of learning and instruction.

The 5 E model uses the methods of engagement, exploration, elaboration, explanation, and evaluation. During the treatment unit, students were given some
examples of matter and some examples of non-matter. The students worked in small
groups to separate the item into groups of matter, unsure, or not matter. The purpose of
this engagement activity was to engage prior knowledge about matter and to identify any
misconceptions. The explore stations included simple, common examples of elements,
compounds, and mixtures. Students worked in small groups to explore the actual
substances and models of the substances and created a diagram from the models. For the
explain activity, the students compare drawings and work with the teacher to define the
types of matter. The next explore stage had the students engaged in mixture separation
stations. Next, the class discussed the explore activity results and recorded important
information from each station in their notebooks as directed by the teacher. For the
elaborate activity, students were given an unknown mixture and had to separate the
mixture. For the evaluate step, the students moved around to stations with different
physical separation techniques. At each station, the students described the physical
separation based on the physical properties and used vocabulary terms from the lesson in
their description.

Students were given the Science Attitude Survey before the non-treatment
astronomy unit (Appendix B). This survey collected feedback about students’ perceived
abilities, interests and attitudes in science. The students also completed the survey after
the 5E treatment in order to compare the Likert scale scores. The scores from the attitude
survey were used to determine if the treatment had a positive effect on student attitudes.
In this scale, a score of 4 represented Strongly Agree, a 3 signified Agree, a 2 represented
Disagree, and a 1 indicated Strongly Disagree. Each question was looked at to see if
attitudes showed improvements or net increase in positive (agreement) responses. The frequency of responses to each answer type from the Science Attitude Survey from before the non-treatment unit, before the treatment unit, and after the treatment unit were compared in a bar graph to determine the effects of 5 E inquiry-based units on student attitudes.

The Astronomy Pre and Post-Assessment was used as a performance assessment to measure student understanding of the science concepts in the non-treatment unit (Appendix C). The five-question assessment was based on Minnesota State Science Standards. The Matter Pre and Post-Assessment was used as a performance assessment to measure student understanding of the science concepts in the treatment unit (Appendix D). The five-question assessment was based on Minnesota State Science Standards. Scores from the Astronomy Pre and Post-Assessment and the Matter Pre and Post-Assessment were used to assess student learning. Assessments were administered before and after the direct instruction unit and pre- and post-treatment. Each student’s pre and post-scores was compared for gains. Class average gain scores determined from the pre-assessment were used to compare the content learned from the direct instruction unit to content attained in the 5 E learning cycle unit. Normalized gain scores were calculated to compare and evaluate the scores. Normalized gains greater than 0.7 showed high gains, medium gains were between 0.31 and 0.7, and low gains were any score below 0.3. The mean, median, and mode were compared. Boxplots were created to compare the data to a normal distribution.
Before the treatment, a group of ten students were randomly selected to provide input through Student Inquiry Interviews conducted post-treatment about their science experience (Appendix D). Student responses provided qualitative data on their attitudes about science and the use of the 5 E method. Interview data was analyzed for themes and used to support evidence from the Science Attitude Surveys and pre and post-assessments. During the treatment unit on matter, the 5 E guided inquiry methods were used throughout the unit. Students were also given the Science Attitude Survey before the treatment matter unit. The non-treatment unit lasted three weeks.

The 5 E Reflection Questions were used to assess the effects of 5 E inquiry-based units on student attitudes (Appendix E). Reflections were written throughout the direct instruction and 5 E learning cycle units. Observations were recorded daily on teacher’s perception of student attitudes. Reflections and observations answered the questions listed in the 5 E Reflection Questions. Teacher reflection data was analyzed for themes and used to support evidence from the Science Attitude Survey and pre and post-assessments.

The Minnesota Comprehensive Assessments (MCA) in science is an assessment of the science learned at grade levels. The grade 8 MCA assesses the sixth through eighth grade standards and is taken in May. The percentage of students who passed the MCA from the previous year was compared to the scores from the eighth grade students in the treatment group. The Data Triangulation Matrix in Table 1 outlines the data collection methods that were used to determine the effect of 5 E learning cycle inquiry-based units.
on student attitudes and content acquisition in middle school science classes compared to direct instruction methods.

Table 1
Data Triangulation Matrix

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Data Source 1</th>
<th>Data Source 2</th>
<th>Data Source 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the effects of 5 E inquiry-based units on student attitudes?</td>
<td>Science AttitudeSurvey</td>
<td>5E Reflection Questions</td>
<td>Student Inquiry Interviews</td>
</tr>
<tr>
<td>What are the effects of 5 E inquiry-based units on content acquisition in middle school science classes?</td>
<td>Astronomy Pre and Post Assessments Matter Pre and Post Assessments</td>
<td>MCA Scores</td>
<td>Student Inquiry Interviews</td>
</tr>
</tbody>
</table>

DATA AND ANALYSIS

Data from surveys, assessments, interviews, and reflections were used to determine the effect of 5 E learning cycle inquiry-based units on student attitudes and content acquisition in middle school science classes compared to direct instruction methods. Before the non-treatment unit, 97% of the students agreed or strongly agreed they learned science best with hands on activities (N=37). Before the treatment this number decreased to 92% of the students and then to 89% after the treatment (Figure 1). One student reported, “I am a kinesthetic learner so I like to learn with my hands.” Another students said, “Yes, I like to do experiments in small groups.”
Only 62% of the students agreed or strongly agreed they do not like to learn by reading from a textbook and taking notes before the non-treatment unit. After the non-treatment unit, which was text and note-based, this number increased to 65% and then decreased to 45% after the 5 E inquiry based treatment unit (Figure 2). The students reported in the interview that most of them would rather do real science as opposed to memorizing notes and taking tests. Students agreed the experiments in class were real science.
Figure 6. Percentages of strongly agree and agree responses to the prompt I DO NOT LIKE TO LEARN BY READING FROM A TEXTBOOK AND TAKING NOTES, from the Science Attitude Survey Results (Item 2), (N=37).

Most students do not think they get to decide what they learn in science class. The majority (78%) of the students did not think they got to decide before the non-treatment, which increased to 89% after the non-treatment. After the treatment unit this number dropped to 70% (Figure 3). When students were asked in the interview if they would like to decide what to study, one student said, “Yes, because some topics are more interesting than others.” Students were concerned that they would not learn enough, or would not know about all the important topics in science if they got to decide. One student said, “It would be good to choose sometimes.”
A low of 40% before the non-treatment, up to 43% before treatment, and a high of 49% of the students agreed that they wanted to be scientists after the treatment (Figure 4). The percentage of students that thought they were good at science was 84% before and after the non-treatment, which dropped to 73% after treatment. When asked the same question in the student interview, one student said they were “kind of good at science.” In the previous year (2014), 78% of the 8th grade students scored at or above with the score of 850 or more on the Minnesota Comprehensive Assessments in science. Of the treatment group, 70% scored at or above an 850.
Figure 8. Percentages of strongly agree and agree responses to the prompt I WANT TO BE A SCIENTIST, from the Science Attitude Survey Results (Item 5), (N=37).

A majority (95-97%) of the students reported science was necessary to help our world. Students’ reported interest in science increased from 86% before to 92% after the non-treatment and finally to 97% after the treatment (Figure 5). Most students, 86% before and after non-treatment and 76% after treatment, agreed anyone could be a scientist. All the students interviewed would rather learn something that is interesting and important to them even if it is more work than learning some that is not important to them. When asked what they like about science, the students reported doing experiments, problem solving, the variety of topics, and studying the “big picture.”
The results of the Astronomy Pre and Post-assessments showed an increase in scores after the non-treatment unit ($N=37$). The average score on the pre-assessment was 68% compared to 94% in the post-assessment, an improvement of 26%. The highest score on the pre-assessment and post-assessment was 100%. The lowest score on the pre-assessment was 0% and the lowest on the post-assessment was 60%. The median score on the pre-assessment was 80%. The median score on the post-assessment was 100% (Figure 6).
The results of the Matter Pre and Post-assessments showed an increase in scores after the treatment unit (N=37). The average score on the pre-assessment was 23% compared to 55% in the post-assessment, an improvement of 32%. The highest score on the pre-assessment was 60% and on the post-assessment was 100%. The lowest score on the pre-assessment was 0% and the lowest on the post-assessment was 0%. The median score on the pre-assessment was 20%. The median score on the post-assessment was 60% (Figure 7).

Normalized gain scores were calculated for each student for the Astronomy Pre and Post-assessments and the Matter Pre and Post-assessments. Normalized gains greater than 0.7 showed high gains, medium gains were between 0.31 and 0.7, and low gains
were any score below 0.3. The average score was 0.68, which indicated medium gains on the Astronomy Post-assessment. On the Matter Post-assessment the average score was 0.43, which also indicated medium gains.

INTERPRETATION AND CONCLUSION

The purpose of this study was to determine the effect of 5E learning cycle inquiry-based units on student attitudes and content acquisition in middle school science classes compared to direct instruction methods. The Science Attitude Survey Questions were designed so agreement or an increase in agreement meant an increase in positive attitudes about science and in thoughts about inquiry-based activities. Questions 1-4 in the Science Attitude Survey dealt with how students learned and what they thought about activities in science class. The questions asked if students learn best by doing hand-on activities, reading from a textbook, if experiments in class are real science, and if students get to decide what to learn in science class. The percentage of students who agreed with these questions decreased after the 5E treatment. This indicated students were not comfortable by learning in a 5E unit compared to a direct instruction unit.

Questions 5-10 on the Science Attitude Survey were about how the students perceived their abilities and their interest in science class. Questions 9 and 10 were about the importance and difficulty of science. More students thought they wanted to be a scientist after the 5E unit which could mean that the methodology was more engaging than a traditional lecture unit. Since fewer students thought they were good in science and fewer perceived their classmates thought they were good after the treatment unit, this could also indicate students were not comfortable with their role in the treatment unit.
Students' interest in science increased after the treatment unit. Student's view of the importance of science increased after the treatment and fewer students thought anybody could be a scientist after the treatment unit.

Though students showed a greater average increase in scores on the matter assessment from the 5 E treatment unit than on the astronomy assessments, the average gain score for the matter assessments was lower than the astronomy assessments. Students had higher average pre-assessment scores on the astronomy than on the matter assessment. Since students knew less about the topic and had a lower average gain score could have lead to students' feelings about their abilities before and after the 5 E matter unit.

To improve this project, the study could have included two groups. On group would be the non-treatment and the other would be the treatment for a unit. For the next unit their roles would be switched. This could be alternated for four or more units and assessments scores and attitude surveys could be compared throughout. Overall, the 5 E treatment unit on matter lowered students' confidence in their abilities in science while simultaneously making them more interested in science and in becoming scientists.

VALUE

Throughout my education as an educator, I was taught the 5 E instructional method is a best practice in science education. I learned the 5 E method can be uncomfortable for teachers and students when they first experience the method and as they develop their skills. Through my reflections during this project I found I quickly tired of direct instruction methods though it was easy to prepare for. The 5 E unit was
more work to prepare and left me feeling uncomfortable as students were left to develop their own understandings of the concepts. Overall, I enjoyed my role during the treatment unit.

This study showed students were less confident about their abilities in science after the 5 E unit, but more interested in science. As a result of this action-based research project I changed as a teacher because I can see how the difficulty and challenge of science is what makes it appealing to students. In the future, I plan to continue to develop my science inquiry skills and include more inquiry in my classroom. This project prepared me for future action research projects. My next action research project is already taking shape. A coworker and I are designing a project for a course that provides an environment where students are developing engineering and scientific inquiry skills by self-choosing standards, researching, and creating experiments and models to answer their own questions. This project allowed me to develop my writing and research skills. I also see more value in peer review because of the writing process we used. I plan to use more peer review activities in lessons so students can help each other and reflect on their own learning.
REFERENCES CITED


APPENDICES
APPENDIX A

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

1. **I learn science best with hands-on activities, such as doing experiments or using models.**
   
<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

2. **I DO NOT like to learn by reading from a textbook and taking notes.**
   
<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

3. **The experiments we do in science class are real science.**
   
<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

4. **I get to decide what to learn in science class.**
   
<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

5. **I want to be a scientist.**
   
<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

6. **I think I am good at science.**
   
<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

7. **I think science is interesting.**
   
<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

8. **My classmates see me as being good at science.**
   
<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

9. **Anyone can be a scientist.**
   
<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

10. **Science is necessary to help our world.**
    
    | Strongly Agree | Agree | Disagree | Strongly disagree |
    |----------------|-------|----------|-------------------|
APPENDIX B

ASTRONOMY PRE AND POST ASSESSMENT
Answer the following questions.

1. Which planet in our solar system is the largest?

2. Name one planet that is closer to the sun than Earth.

3. Which motion of the Earth causes night and day?

4. How long does it take for the Earth to travel 360 degrees around the sun?

5. What is the name of the galaxy that you live in?
APPENDIX C

MATTER PRE AND POST TREATMENT ASSESSMENT
Answer the following questions.

1. What is the difference between a mixture and a compound?
2. What is a pure substance?
3. Describe one way metals are different than non-metals.
4. Give one example of a physical property.
5. Give one example of a chemical property.
APPENDIX D

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

1. Do you learn science best when you read from a textbook?
2. Would you like to decide what to study in science class?
3. Are you good at science?
4. Do you learn science best when you use hands-on activities, such as labs or models?
5. Would you rather memorize notes and take tests or have the chance to do real science?
6. Would you rather learn something that is important to you even if it means more work or learn something that might not interest you but is easy?
7. What do you like about science?
8. Is there anything else you would like me to know?
APPENDIX E

TEACHER REFLECTION QUESTIONS
1. Did I feel motivated while teaching today?

2. What is my attitude about the current lesson/classroom activities?

3. Are the students meeting my learning expectations?

4. Any ideas or suggestions for improvement?

5. What do I think about the students’ attitudes and motivation?

6. Did I follow the 5E model (during treatment)?

7. Is the treatment making an impact on student learning?
APPENDIX F

IRB APPROVAL
INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

MONTANA
STATE UNIVERSITY

MEMORANDUM

TO: Kyle Casper and John Graves

FROM: Mark Quinn, Chair

DATE: November 24, 2014

RE: "Increasing Student Achievement in Science through the Use of the 5 E Instructional Method"
[KC112414-EX]

The above research, described in your submission of November 24, 2014, 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.