USING THE VAN ANDEL EDUCATION INSTITUTE'S MODEL OF SCIENTIFIC INQUIRY IN THE FOURTH-GRADE CLASSROOM

by

Brian Staggs

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

©COPYRIGHT

by

Brian Staggs

2015

All Rights Reserved

DEDICATION

I am thankful for the support and encouragement provided by Dr. Peggy Taylor, Diana Paterson, and Holly Thompson in the MSSE program office. I would like to acknowledge the wise council and guidance provided by my graduate committee and express my gratitude to Dr. Walt Woolbaugh, Amber Kirkpatrick, and Ken Bergwerff. Thank you to Dr. Lindsay Ellis and her family for sharing and supporting my family and myself in a memorable year of study in Utrecht, Netherlands. Thank you to Dr. Lindsay Ellis and Dr. Stephen Staggs for reading through drafts of my work and providing a model of excellence in academia. Thank you to my parents, Tom and Anna Staggs. I dedicate this work with love and thanks to my wife, Becky Staggs, and my three children, Greta, Amelia, and Cormac. Without your love, encouragement, and patience this project would be less complete. You are joy in my life.

TABLE OF CONTENTS

1. INTRODUCTION AND BACKGROUND 1

2. CONCEPTUAL FRAMEWORK 5

3. METHODOLOGY 13

4. DATA AND ANALYSIS 20

5. INTERPRETATION AND CONCLUSION 41

6. VALUE 45

REFERENCES CITED 49

APPENDICES 53

APPENDIX A $QPOE_2$ Graphical Representation of the Science Inquiry Model 54
APPENDIX B Sample QPOE2 Step Book Page 56
APPENDIX C Origins and Development of Instructional Models 58
APPENDIX D BSCS 5E Instructional Model 60
APPENDIX E Pre and Post Unit Student Survey Questions 62
APPENDIX F Pre and Post Unit Student Interview Questions 67
APPENDIX G Concept Maps: Non-treatment and Treatment 70
APPENDIX H Concept Map Rubric 72
APPENDIX I Capstone Timeframe 74
APPENDIX J Institutional Review Board Exemption 76
APPENDIX K Sample Student Concept Maps 78
APPENDIX L Likert Survey Results Student Attitudes and Motivation 80

LIST OF TABLES

1. Data Triangulation Matrix 18
2. Likert Survey Questions Probing Students' Understanding of Science Concepts 26
3. Student Response to Classroom Survey After $QPOE_2$ Treatment.....31
4. Student Response to Classroom Survey after $QPOE_2$ Treatment - Attitude and Motivation in the Science Classroom 38
5. Origins and Development of Instructional Models.....59
6. BSCS 5E Instructional Model.....61
7. Likert Survey Questions Probing Students' Attitudes and Motivation in the Science Classroom in December.....81

LIST OF FIGURES

1. Pre and Post Test Unit Assessment.....21
2. Post Test Non-treatment Unit Grade Distribution.....22
3. Post Test Treatment Unit Grade Distribution.....23
4. Concept Map.....25
5. Likert Student Survey Response.....37
6. Question Probe Student Survey.....39
7. $QPOE_2$ Graphical Representation of the Science Inquiry Model.....55

ABSTRACT

Teaching science through inquiry is a goal of science education. The definition of inquiry is quite varied, and its implementation is hindered by a number of well-documented factors. The literature describes scaffolded inquiry instruction as a successful method for incorporating inquiry in the classroom. In this action research project, one model of an inquiry scaffold called $QPOE_2$ was introduced to a fourth-grade classroom. Through unit assessments, concept mapping, student interviews, student surveys, and teacher observations, data was compiled to measure its effectiveness on student scientific understandings, engagement in scientific argumentation, and motivation for science in the classroom. While unit assessments indicate student scientific understandings did not improve as significantly following treatment with this model of inquiry, concept-mapping data indicate that students did make similar gains in scientific understanding following instruction with the $QPOE_2$ model. Data indicates that following instruction with the $QPOE_2$ model, students' understanding and ability to engage in scientific argumentation and student motivation improved. Implications of this project highlight the powerful motivational effects experienced by students when engaging in science through a scaffolded inquiry approach.

INTRODUCTION AND BACKGROUND

Project Background

In September 2012 I joined the Kent Intermediate School District's (KISD) Kent Science Team. Today I continue to serve and work with this team. Our team was tasked with understanding the changes recommended by the Next Generation Science Standards and the effect these changes would have on our curriculum, instructional practices, and ultimately our students. I was a rare participant on this team. The majority of teacher participants on the Kent Science Team teach science at middle school or high school level. At that time I was the lone elementary science specialist. In my weekly teaching responsibilities for Grandville Public Schools, I instructed laboratory experiences for more than 700 first through sixth-grade students at three elementary buildings.

In September 2014 my teaching responsibilities changed. I was placed as a fourth-grade teacher at East Elementary School in Grandville, Michigan. Due to budget constraints, the number of elementary science specialists in Grandville Public Schools was decreased from three full-time instructors to two full-time instructors. In addition, the elementary science laboratory class was limited to third through sixth-grade students. Through my current work as a generalist elementary teacher and previous work as an elementary science specialist, I have become acutely aware of the challenges faced in elementary science instruction.

Grandville Public Schools is unique with respect to science instruction in Kent County; having created this elementary science specialist position over 25 years ago to assist elementary teachers who lacked a background and familiarity with science

concepts. The elementary science specialist's role is to form an instructional team with the homeroom teacher. This instructional relationship positively addresses many issues surrounding science in the elementary classroom. However, a full inquiry framework has been difficult to achieve in both elementary science classrooms and elementary science laboratories. In fact, students are not specifically taught a scientific inquiry process until sixth grade. A host of limiting factors contributes to this phenomenon. Chief among these factors include limited time available for each science session, teacher and school evaluations based upon reading and math score improvements, current state science tests covering broad-based factual knowledge, and the complications faced by elementary science specialists when working with multiple homeroom teachers.

The major urban center in Kent County is Grand Rapids, Michigan. In 1996, a prominent business owner and his wife, Jay and Betty Van Andel, created the Van Andel Institute next to the major hospital in Grand Rapids. The Van Andel Institute contains two arms: the Van Andel Research Institute (VARI) and the Van Andel Education Institute (VAEI). The mission of the Van Andel Education Institute is to strengthen inquiry-based science education and provide opportunities for students at various education levels to think and act like scientists (Triezenberg, 2014).

The Van Andel Education Institute has developed an instructional scaffold for teaching science through inquiry within its education programs called $QPOE_2$. An instructional scaffold allows an educator to break apart a complex task into smaller parts that allow a student to achieve a learning goal. The acronym $QPOE_2$ represents Question, Prediction, Observation, Explanation and Evaluation. Its structure is presented to

students through three different visual mediums: a graphic organizer (Appendix A), a step book (Appendix B), and an application for tablet devices. The Van Andel Education Institute presents this scaffold to area science teachers through professional conferences and professional development days at the institute.

The Next Generation Science Standards are built upon the National Research Council's (NRC) 2012 publication, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas*. This framework called for science education in the United States to be built around three major dimensions: scientific and engineering practices, cross-cutting concepts that unify the study of science across disciplines, and core ideas from four scientific disciplines (NRC, 2012).

This framework was the catalyst for my action research project and focus questions. This question carries personal weight for me as a teacher for a number of reasons. First, serving on the Kent County Intermediate School District science team has raised my awareness of the importance of teaching science through inquiry as advocated by the previous national science standards and the Next Generation Science Standards. Second, I have participated in Van Andel Education Institute $QPOE_2$ trainings multiple times but have not had the opportunity to incorporate it into my teaching and wanted to measure its effectiveness and motivational impacts within my classroom. Third, students should be exposed to the nature of science at the elementary level. Young students are naturally inquisitive and learning how science builds a body of knowledge is important for their work within scientific disciplines. This model exists to assist teachers in instructing

students within an inquiry framework, and I was interested in measuring its effectiveness at the elementary level.

Focus Questions

My focus and sub questions for this project were: What effects does using the Van Andel Education Institute's science inquiry strategy, $QPOE_2$, have on elementary students' understanding of science concepts? Sub question 1: What are the effects of using $QPOE_2$ on students' scientific argumentation and evaluative skills; Sub question 2: What are the effects of using $QPOE_2$ on students' attitudes and motivation within the science classroom; and Sub question 3: What are the effects of using $QPOE_2$ on my teaching and motivation? While this project is specific to my position, many districts around the nation will be faced with the same task of implementing the Next Generation Science Standards within their elementary schools. Results of this project may help in that transition and/or have broader applications for science teaching in general.

Support Team

I had three members of a support team assist me with the production of this action research project. All three are well versed in pedagogical frameworks and academic writing. Professor Ken Bergwerff taught middle school science for a number of years and currently researches and teaches in the field of science education at Calvin College. Dr. Stephen Staggs taught elementary social studies, high school history, and recently completed his doctorate in history from Western Michigan University. He currently teaches undergraduate history courses at Calvin College and Western Michigan University. Dr. Lindsay Ellis teaches English education and serves as a Faculty Writing

Director at Grand Valley State University. Dr. Ellis teaches courses on action research and has assisted me in proofreading drafts of this document.

CONCEPTUAL FRAMEWORK

Inquiry is a major goal of the science reform movement. The National Research Council identified inquiry as a goal in its 1996 publication of national science standards. Inquiry, in a historical context, has a much longer history originating in the beginnings of western philosophy as practiced by Socrates in Greece. The Socratic method influenced western thought during the Renaissance and the Age of Enlightenment. At the turn of the 20th century the educational philosopher John Dewey articulated a modern view of inquiry in formal education. In his 1897 article, *My Pedagogic Creed*, Dewey expresses a desire for school to meet the interests of the child and not to place the child in the role of a passive, absorbing participant. Dewey articulates a belief in the expressive or constructive nature of education. He writes that the teacher is not a figure of knowledge imposition, but a member of the community who guides the child in engaging with the discipline of life (Dewey, 1897). The notion of the learner engaging with and constructing knowledge for him/herself was at the core of the development of inquiry during the next 100 years.

Between 1896 and 1996 inquiry and its role in education and science education in particular was further developed through educational research, cognitive psychology, and epistemological thought. In a report prepared for the Office of Science Education and the National Institutes of Health, Bybee, Taylor, Gardner, Van Scotter, Carson, Westbrook and Landes (2006) document the major instructional models developed throughout this

time period: Johann Friedrich Herbart (1901), John Dewey (1916), Heiss, Obourn, and Hoffman (1950), Atkin and Karplus (1962), and the Biological Sciences Curriculum Study (BSCS) (1989). Appendix C presents a summary of these instructional models (Bybee et al., 2006). The BCSC 5E model (Engagement, Exploration, Explanation, Elaboration, and Evaluation) of scientific inquiry is a well-established model for science instruction that has existed in its current form since 1989. A table explaining the BSCS 5E model is found in Appendix D.

Despite its ubiquitous use throughout the educational landscape, a unified definition of inquiry continues to be elusive and problematic (Minner, Levy, & Century, 2009). What is meant by inquiry provokes much disagreement in educational literature (Lederman, Lederman, & Antink, 2013). The view of inquiry held by teachers is also variable (Abell, & Smith, 1994; Biggers, & Forbes, 2012; Davis, & Smithy, 2009).

Some guiding documents published by the National Research Council (NRC) over the past 18 years help clarify the nature of inquiry in broad terms. In its first set of national science standards, the NRC articulated a broad definition of inquiry. Inquiry was described as; the way scientists study and propose explanations of the natural world derived from evidence, the activities students perform to acquire scientific knowledge and understanding, and the understanding students develop of the manner in which scientists study the natural world (NRC, 1996).

In its most recent iteration, the operational framework of inquiry has been refined into eight key practices to be used in collaboration with crosscutting concepts and core ideas. These practices are: 1) asking questions/defining problems, 2) developing/using

models, 3) planning/performing investigations, 4) analyzing/interpreting data, 5) using mathematics and computational thinking, 6) explanations/solutions, 7) evidence based argumentation, 8) obtaining, evaluating, and communicating information (NRC, 2012).

The publication of the Next Generation Science Standards (2013) that were developed based on the 2012 Framework refines this newer vision of inquiry. Inquiry is specified by the 8 practices found throughout every performance expectation (NGSS, 2013). It is when integration of the practices and content occur that science begins to make sense and becomes meaningful to students (NGSS, 2013).

The NRC and the NGSS, however, leave open the "how" of this integration of practice and content. This broad definition has historically been both its strength and its weakness. Its weakness is that researchers and educators are left trying to characterize inquiry in action (Anderson, 2002). A review of the literature reveals the contradictory conclusions regarding inquiry that invariably arise as a result of this broad definition of inquiry. Its strength, however, is that it allows for a range of interactions between student and teacher that constitute inquiry. This range of interactions has generated a list of operational truths regarding inquiry practices.

An examination of the literature reveals some of these operational truths that serve as guideposts for the classroom. Inquiry learning is not pure discovery but is most successful when scaffolded or guided by an educator. Richard Mayer (2004) reviewed the previous three decades of research on pure discovery learning versus guided discovery learning. His research demonstrates that "*constructivism = hands-on activity* is a formula for educational disaster" (p. 17). Mayer concludes that in pure discovery

students may not encounter the material to be learned and, even if encountered, there is no magical process whereby contact creates meaning for them (2004).

Kirschner, Sweller, and Clark (2006) also document evidence from research that minimally guided discovery-learning fails to promote scientific understanding and, in fact, can have a detrimental effect on promoting scientific understanding. While research does not support pure discovery learning, Hmelo-Silver, Duncan, and Chinn (2007) present evidence through published research indicating successful inquiry learning is not pure discover learning, but employs a range of scaffolding. This scaffolding of inquiry allows students to learn more complex topics through a reduction in the cognitive load.

Inquiry learning is not the traditional linear scientific method. The NRC articulates an understanding of inquiry as a series of practices that allows students to participate in science and build scientific knowledge (2012). These practices do not operate within a beginning and end. Research demonstrates, however, that pre-service and beginning teachers continue to equate inquiry with the scientific method (Windschitl, Thompson, & Braaten, 2007). Windschitl, Thompson, and Braaten advocate teaching pre-service and beginning teachers a circular framework for inquiry with a goal of generating defensible understandings of the natural world. While sharing many characteristics with the scientific method, a circular model of inquiry more closely resembles the process of science as practiced by scientists and envisioned by the NRC and the NGSS.

The National Science Foundation provided a grant to fund a meta-analysis of inquiry within the K-12 classroom. The Inquiry Synthesis Project collected, coded, and

evaluated published inquiry studies from the years 1984 – 2002. The resulting document evaluated 138 studies and found a clear positive trend favoring inquiry-based instructional practices (Minner, Levy, & Century, 2009). Results suggest that when properly scaffolded, inquiry learning has a positive effect on student proficiency. Out of 138 included studies, 42 were comparative studies and more than half of these studies found that increased inquiry saturation provided statistically significantly better competency results than lower amounts of inquiry within science instruction (Minner, Levy, & Century, 2009).

Wilson, Taylor, Kowalski, and Carlson (2010) conducted a laboratory-based randomized control study involving 58 students between the ages of 14 – 16. Results of the study supported the concept that scaffolded inquiry science instruction improves student assessment performance. Students were placed in one of two groups with the same instructor who used two different instructional models. One group received instruction based around the BSCS 5E instructional model. The second group received instruction based upon commonplace teaching practices as reported through a national teacher survey. At the end of the instructional unit the group receiving the BSCS 5E instruction showed significant gains in achievement in areas of scientific knowledge, scientific reasoning, and scientific argumentation. The inquiry-based group of 30 students had a mean pre-test score of 29.23 out of 74 and an adjusted post-test score of 47.12 out of 74, while the commonplace group of 28 students had a mean pre-test score of 31.11 out of 74 and an adjusted post-test score of 42.87 out of 74. (Wilson et al., 2010).

Geier, Blumenfeld, Marx, Krajcik, Fishman, Soloway and Clay-Chambers (2007) researched the effect of implementation of an inquiry curriculum in 18 Detroit Public School classrooms as measured by the Michigan Educational Assessment Program (MEAP). In total two different groups receiving the intervention curriculum were compared with students who did not receive the intervention (Geier et al., 2007). Results revealed that students in group 1 achieved a 14% improvement in total score and achieved higher scores in all three areas of the science assessment compared to their peers not engaged with the inquiry curriculum (Geier et al., 2007). In the significantly larger group 2, students achieved a 13% improvement in their total science score compared to their peers not receiving the inquiry curriculum (Geier et al., 2007).

Scientific argumentation is an important feature of inquiry learning, and the NRC includes scientific argumentation in its eight key practices of science (2012). In common usage, argumentation is viewed as both a competitive and negative act. In science, however, argumentation is not competitive and is not viewed as a negative enterprise. Instead, explaining and evaluating claims from evidence (argumentation) is the means through which science generates an agreed upon body of knowledge.

Science classrooms often neglect this aspect of inquiry. Researchers in the area of scientific argumentation in junior high schools have noted, "Deliberative discussions have commonly occupied only 2% of all science lessons" (Osborne, Erduran, & Simon, 2004, p. 997). In many classrooms, science is still seen as the transmission of uncontested facts (Osborne, 2010). However, engagement with scientific argumentation fulfills three goals of the science reform movement: it allows students to move past the

often-implied view of science as an uncontested body of facts, it increases students' understanding of the nature of science, and it improves students' understanding of science concepts.

Evidence for the connection between making time for argumentation within the science classroom and improved student performance has been documented. A group of students in a second-grade classroom in Nevada were coached in the art of scientific argumentation and making claims from evidence. Through scaffolded instruction, these second-grade students were taught to present and evaluate claims from evidence. The students who engaged in scientific argumentation showed a 69% increase in their understanding of the science concepts as measured through a pre and post test survey (Fulton & Poeltler, 2013). Students in a comparative second grade classroom who did not engage in scientific argumentation demonstrated a 21% increase in their pre and post test results (Fulton & Poeltler, 2013).

In a much larger study, Richard Hake (1998) conducted pre and post test cognitive measurement surveys with over 6,000 students participating in introductory physics courses taught at high schools, colleges, and universities. Results indicated that students who engaged in argumentation and evaluation discussions with peers and teachers during the course (courses taught with an interactive-engagement model) exhibited significantly higher gains (0.48 +/- 0.14) versus students taught in traditional style physics courses (0.23 +/- 0.04) (Hake, 1998).

Along with a fundamental educational investigation another core question generated by my action research is: What motivational impact does the educational

intervention being introduced have on students and teachers? Teacher and student motivation is complex and multi-faceted. Studies hint at the positive impact of inquiry on motivation. Palmer (2009) measured the situational interest during an inquiry-based lesson with 224 grade nine students. Throughout the lesson, participants reported a higher degree of interest during the inquiry tasks conducted compared to the traditional note-taking activities (Palmer, 2009).

A study conducted by Pickens and Eick (2009) surveyed 28 students in an AP high school biology course and 22 students in a tenth-grade physics course on motivational factors. Students reported peer-peer and peer-teacher dialogue, positive classroom environment, self-confidence, and engaging in inquiry activities as the main motivating factors within their science classroom (Pickens & Eick, 2009).

Work by Skinner and Belmont (1993) hints at the reciprocal relationship of the student and teacher. In a study conducted among 144 elementary students and their 14 teachers, Skinner and Belmont (1993) documented that teacher behavior influences student engagement. Reciprocally, student engagement strongly impacted teacher behavior (Skinner & Belmont, 1993). If inquiry can improve student engagement and motivation, then a similar effect should be seen in the teacher.

My action research project seeks to build upon the work of previous practitioners examining instructional models in the classroom. The main question this project seeks to answer is whether the incorporation of a locally developed model of inquiry is positive and feasible within an elementary fourth-grade classroom. Specifically, this project is investigating the effectiveness of the Van Andel Education Institute's scaffolded inquiry

process, $QPOE_2$, in 1) increasing elementary students' scientific understandings, 2) increasing elementary students' ability to successfully engage in scientific argumentation, 3) increasing student motivation in science class, and 4) increasing teacher motivation for science instruction.

METHODOLOGY

Project Treatment

For this project, six units of instruction were compared. Three units of earth science were completed following traditional teaching methods. Topics addressed during the non-treatment units included the layers of the earth and the rock cycle, minerals and their identification, and renewable and nonrenewable natural resources. Following these units, three units of physical science were completed following the $QPOE_2$ protocol. Topics addressed during these units included different forms of energy: heat, sound, and electric.

Non-treatment instruction followed a traditional method of elementary science instruction. Students received factual information through teacher instruction, selected images, video segments, supplemental readings, guided note taking, model building, projects, earth resource samples and mineral testing.

Three main topics of earth science were delivered during the non-treatment units. First, students learned about the rock cycle through production of a rock collection and guided notes. Students received an egg carton, a collection key, and a 4-page handout. Students numbered the egg carton 1–12 and glued the collection key into the lid of the egg carton. Over the course of 3 weeks samples of sedimentary (3), metamorphic (3),

and igneous (4) rocks and minerals (2) were passed out to students. Students learned about the specifics of each rock through teacher instruction, images, and video segments. As students received their samples they followed the teacher's model and completed a series of notes about each sample in their guided notes.

Second, over the course of two weeks students were guided through a PowerPoint presentation and learned about minerals and some of the ways scientists identify mineral specimens. Students were then given a series of tools to conduct their own identification tests. Piles of eight different mineral specimens were arranged around the room. Students worked with a partner to test and record data about each separate mineral sample. Students were expected to test for luster, color, streak, hardness, and magnetism. At the end of the second session the teacher went over data collected by the class and the identification of each mineral was provided.

Third, over the course of three weeks students read their textbook and a handout about earth's resources and the difference between renewable and nonrenewable resources. Samples of each resource were provided for students to include in an AIMS Center for Math and Science Education foldable book about earth's resources. Images and video segments were shown to highlight the extraction and production of various types of resources from the earth.

Three physical science units were taught using the $QPOE_2$ inquiry framework of Question, Prediction, Observation, Explanation, and Evaluation: heat, sound and electrical energies. In the first treatment unit students were introduced to the $QPOE_2$ framework and were walked through the inquiry process following the $QPOE_2$ step book

that each student received. An example page from the $QPOE_2$ step book is in Appendix B. Students were shown how to transfer and document their activities in a scientific notebook using the $QPOE_2$ framework, and following the modeling of the teacher; students worked in pairs to complete an investigation involving heat energy. The teacher gathered and compiled student data and worked with students to analyze data, compile an explanation of their investigative results and evaluate the inquiry investigation as directed by the inquiry step books.

The second treatment unit explored sound energy. The process of completing the sound investigation unit mirrored the first. This time, however, students were asked to complete each section of the $QPOE_2$ inquiry process framework with more independence in selecting their investigative question. Students again worked in pairs to plan and complete an investigation into sound energy using straw horns. Partners were encouraged to use classmates and the instructor to assist them in completing the inquiry framework, but were required to have each section of the $QPOE_2$ framework evaluated by the instructor before continuing on to following sections. Partners completed the investigation and again presented their evidence and explanation of their conclusions to the class. Classmates asked further questions and provided feedback on each of the investigations. Finally, students and the instructor evaluated a small sample of the completed investigations; four partner groups out of 11 total groups presented their investigative cycles and scientific arguments. The classroom instructor evaluated completed $QPOE_2$ notebooks.

The third treatment unit concerned electrical energy, and student independence was extended. Students were allowed to complete this inquiry framework individually, with a new partner, or with their previous partner. Students made their partner selection and were again asked to generate an investigable question that could be completed using the $QPOE_2$ inquiry framework. Each step of the inquiry process was documented in student laboratory books and partners were responsible for checking in with the instructor whenever they moved to another section of the $QPOE_2$ framework. Partners presented their investigation evidence and evaluative conclusion to their classmates with a poster and oral presentation. Classmates asked further questions and provided feedback. Students and the instructor evaluated the final $QPOE_2$ posters and oral presentations.

The treatment units consisted of multiple student interactions within the $QPOE_2$ process. The interactions transitioned from highly scaffolded to highly independent. This project documents the ability of fourth-grade students to build scientific knowledge through the $QPOE_2$ framework, and positively impact their motivation to participate and engage with science as a discipline.

Data Collection Instruments

This action research project took place at East Elementary in Grandville, Michigan. East Elementary is one of seven elementary schools located in a suburban community outside of Grand Rapids, Michigan. The majority of Grandville Public Elementary Schools have less than 25% of their students receiving free and reduced lunch; East Elementary is different. East Elementary has 378 students in first through sixth grade. It is also a Title One building and 68% of its student population receives free

and reduced lunch. East Elementary also has a number of incidences where students move out of or into the school throughout the year. This action research project began with 23 students in one fourth-grade classroom, and ended with 23 students. However, over the five-month course of this project, three students left the classroom and three new students joined. For the majority of the project there were 22 students in the fourth-grade classroom.

The gender ratio within this classroom was quite even with 11 females and 12 males. Of the 23 students in this classroom, one is of Black or African American ethnicity, one is of Hispanic or Latino ethnicity, two are of Native American ethnicity and the remaining 19 are Caucasian. Twelve of the 23 students receive additional educational support services. Multiple services are provided to seven students; five receive speech therapy and resource room support, one receives English learner language support and Tier 2 reading intervention support, and one receives Tier 2 reading support. Finally, ten students, six of whom are included in the previous list, receive additional math intervention support.

Qualitative and quantitative data were obtained through a variety of methods in order to answer the focus question and sub questions effectively. Triangulation of data (Table 1) was used to provide a more robust comparison of the treatment intervention to the non-treatment unit of study. Multiple data sources, district unit assessments and a review of survey and interview questions by instructors in the Master of Science in Science Education program of Montana State University helped generate valid and reliable data.

Table 1
Data Triangulation Matrix

	Focus Questions	Data Source 1	Data Source 2	Data Source 3
1.	What are the effects of using the science inquiry strategy, $QPOE_2$, to improve elementary students' understanding of science concepts?	Pre and post unit assessments	Pre and post unit interviews with concept mapping during non-treatment and treatment units	Pre and post unit student surveys during non-treatment and treatment units
2.	What are the effects of using $QPOE_2$ on students' scientific argumentation and evaluative skills?	Post unit peer evaluations	Instructor field observations and post unit instructor evaluations	Pre and post unit student surveys during non-treatment and treatment units
3.	What are the effects of using $QPOE_2$ on students' attitude and motivation within the elementary science lab?	Student daily science reflection survey	Pre and post unit interviews during non-treatment and treatment units	Pre and post unit student surveys during non-treatment and treatment units
4.	What are the effects of using $QPOE_2$ on the teacher's attitude and motivation?	Pre and post unit teacher survey during non-treatment and treatment units	Instructor daily reflection journal	Weekly colleague observation journal

A Likert survey and series of open-ended response questions were administered to the entire class four times over the course of this action research project; before and after each major unit of instruction (Appendix E).

In the fall, all students at East Elementary participate in an on-line assessment developed by the Northwest Evaluation Association called Measures of Academic Progress (MAP). This national norm-referenced test provides a picture of academic progress in reading and math. These reading scores were used to place students into three different academic groups: low, average and high academic achievement groups. Each student in an academic group was assigned a number and two numbers were randomly selected from each group. This stratified randomized selection generated six student interview participants.

Student interviews were conducted throughout the course of the project to measure the effect of the treatment intervention on scientific understanding and student motivation. Along with answering specific interview questions (Appendix F), interviewed students also completed pre and post unit concept maps (Appendix G). Students explained and added additional terms to their concept map during the post unit interview session.

Non-treatment units were conducted over nine weeks beginning in January and finishing the first week of March. Non-treatment units began with the earth's layers and the rock cycle taught over three weeks, followed by mineral identification that took two weeks to complete. The unit finished with natural resources that required another four weeks of instruction. Treatment units were conducted over seven weeks beginning the

second week of March and continuing to the end of April. The first two topics: heat energy and sound energy were taught over two weeks, and electric energy was completed in three weeks (Appendix I). 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 J).

DATA AND ANALYSIS

One fundamental goal of this action research project was to examine the effectiveness of the QPOE$_2$science inquiry strategy for improving elementary students' understanding of science concepts. A common concern among educators as they look at incorporating an inquiry model is a fear of losing content knowledge. A traditional measure of understanding is the classroom assessment, so pre and post tests were administered for the non-treatment earth science unit and the treatment physical science unit. The non-treatment earth science unit test was derived from the classroom science textbook and contained a mixture of vocabulary, multiple choice, and short answer questions. The school districts two elementary science specialists designed the treatment physical science unit test that contained only multiple-choice questions with attached diagrams. To make non-treatment and treatment unit post tests comparable the classroom teacher administered an additional vocabulary test. The vocabulary and multiple-choice questions were combined into one final treatment unit test score. Non-treatment unit pre and post tests were administered to 21 students, and treatment unit pre and post tests were administered to 23 students. Data from non-treatment and the treatment unit assessments indicate student understanding of science concepts did not increase as significantly using

the $QPOE_2$ model as with traditional methods. Average growth scores show a decrease in student achievement between the non-treatment and treatment units' pre and post instruction assessments (Fig. 1).

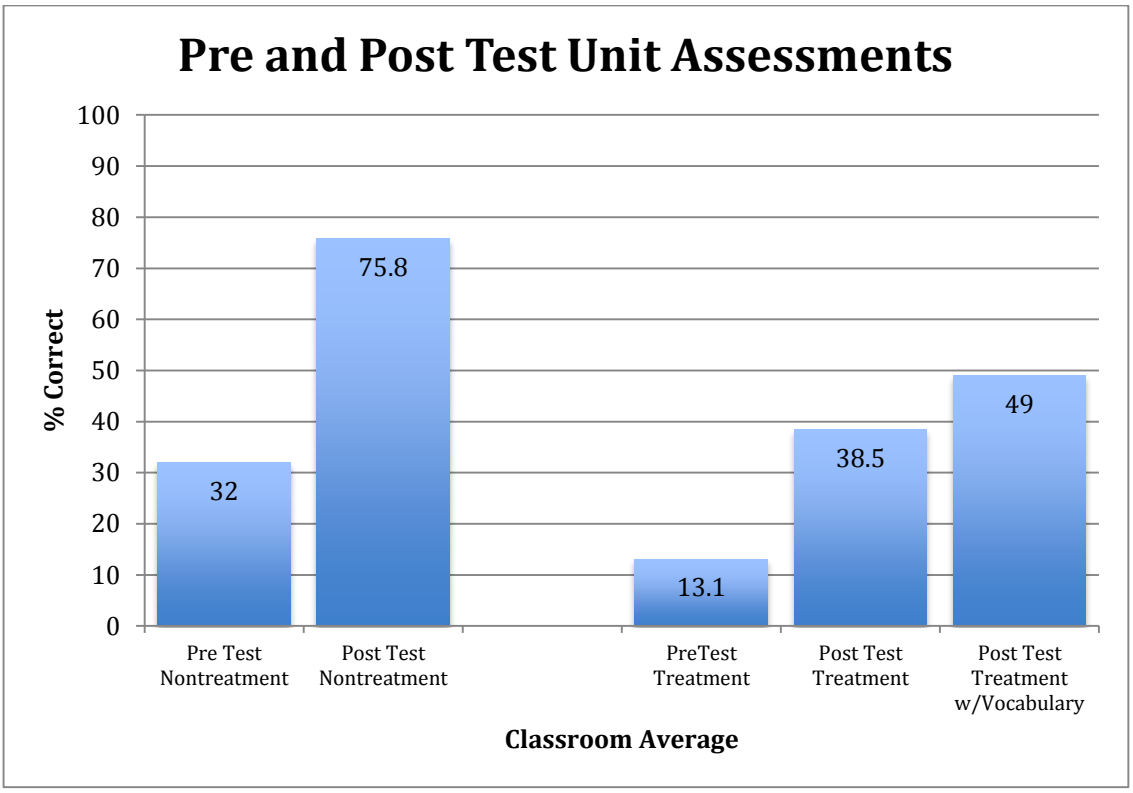


Figure 1. Pre and post test unit assessment, (non-treatment *N*=21, treatment *N*=23).

Analyzing the gain in growth between the pre and post unit assessments demonstrates that the non-treatment unit scores grew by 43.8 percentage points compared to the treatment unit scores which grew by 35.9 percentage points.

Analyzing individual grade distribution on the final unit assessments also highlights this decreased performance for the treatment unit. Figure 2 presents individual grade distributions for the post test assessment of the non-treatment unit. Twelve students scored at or above 80%, with two students getting 100%. Only four students

scored below 60%. I attribute this to traditional science instructional methods allowing for more specific instruction and exposure to a broader number of topics asked on the unit post test.

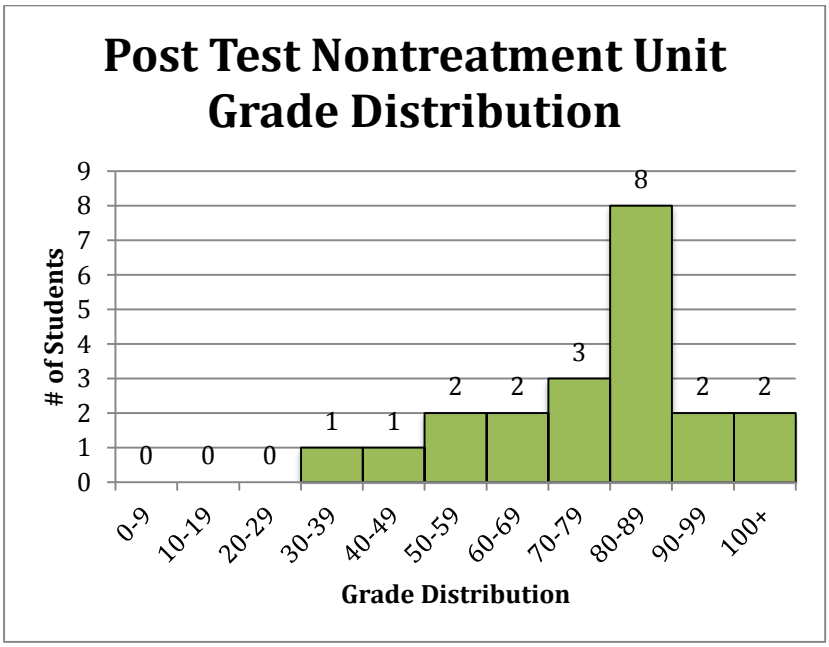


Figure 2. Non-treatment unit post test grade distribution, (*N*=21).

Figure 3 presents individual grade distributions for the post test assessment of the treatment unit. Twelve students in the treatment group scored below 60% on the post test compared to only two students in the non-treatment group. More than half (57.1%) of the non-treatment group students scored 80% or higher, yet only two students following the treatment unit achieved a score above 80%, and no students achieved a score greater than an 84%, following the treatment unit. The dominant score range achieved by the class following the treatment unit was between 60 – 69%. Instructing students in the inquiry process itself demanded a large percentage of instructional time. Students were learning about the inquiry process and were engaged in valuable learning activities, but

less instructional time could be given on material specifically covered by the end of unit test.

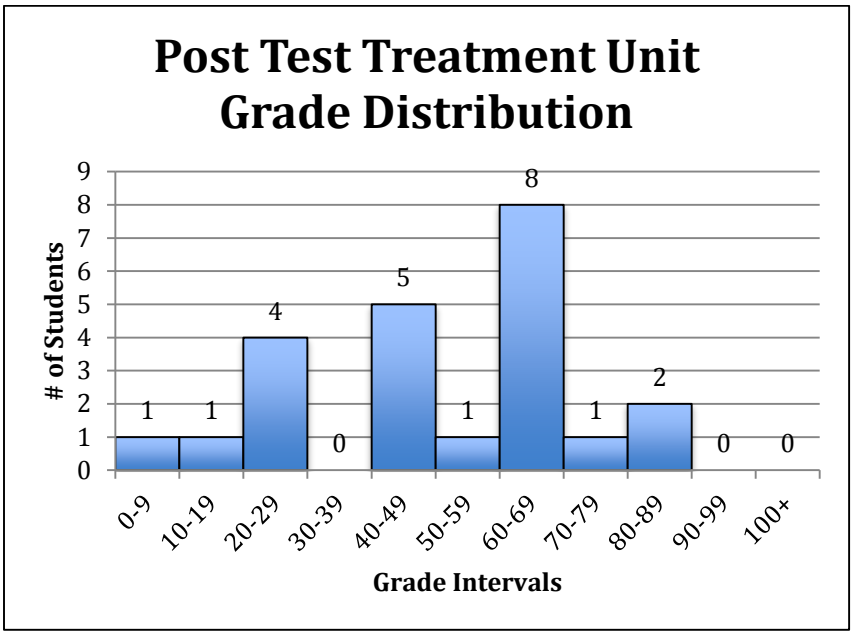


Figure 3. Treatment unit post test grade distribution, (*N*=23).

As I was engaged in the $QPOE_2$ inquiry process I was growing concerned about my students' ability to gain a broader understanding of the various science concepts that would ultimately be tested. This concern was caused by my students' unfamiliarity with any inquiry process. Supporting students in learning about scientific inquiry consumed class time that would have been spent on content knowledge. Journal entries reflected my concern that scaffolding the inquiry process was taking so much classroom instructional time that it was difficult to include robust instruction on the multitude of unit concepts. On March 31, 2015, I reported, "We worked on the explanation portion of the inquiry process today. Students are so unfamiliar with this type of thinking that it is taking a majority of the instructional time. I am surprised that they seem so engaged and

eager to work within this system." This theme of unfamiliarity and time constraint was noted multiple times in my journal. I was concerned that time constraints were causing my treatment to begin to resemble a guided discovery model wherein students would have to "discover" the concepts independently. Instructing students in the inquiry process took time away from the full breadth of expected content knowledge.

While most of the students involved in the student interview process expressed a positive opinion of the effectiveness of the $QPOE_2$ inquiry model, one student expressed a concern at the end of the treatment unit. This student, who receives educational support in reading, stated that the $QPOE_2$ process was interesting and engaging, but "it didn't really teach me." This student recognized the knowledge he was gaining didn't conform to his previous experiences within the science classroom. He expected to gain a broad base of content knowledge within each unit, while the $QPOE_2$ inquiry process provided a more focused knowledge.

It is not possible to imply that the $QPOE_2$ intervention led to a decrease in student understanding. Treatment unit student scores still improved - just not as significantly as in the non-treatment unit. This difference can be attributed to several other factors including the difficulty of test content, test structure, time spent on test practice, and test administration processes. Further data on student understanding was collected through student created concept maps that were built before and after non-treatment and treatment units. Data generated through these concept maps provide a counterpoint to the decrease seen on the treatment unit post test scores.

Before this action research began students were unfamiliar with concept maps. Before the non-treatment unit began, students were introduced to the definition of concept mapping, and example concept maps were introduced to the class. Guided by the teacher, students created practice concept maps using familiar terms and a central theme - house. Students also created a practice concept map using the central theme of family.

Students were given a list of 10 terms to use on their non-treatment earth science concept map and a list of 13 terms to use on their treatment physical science concept map.

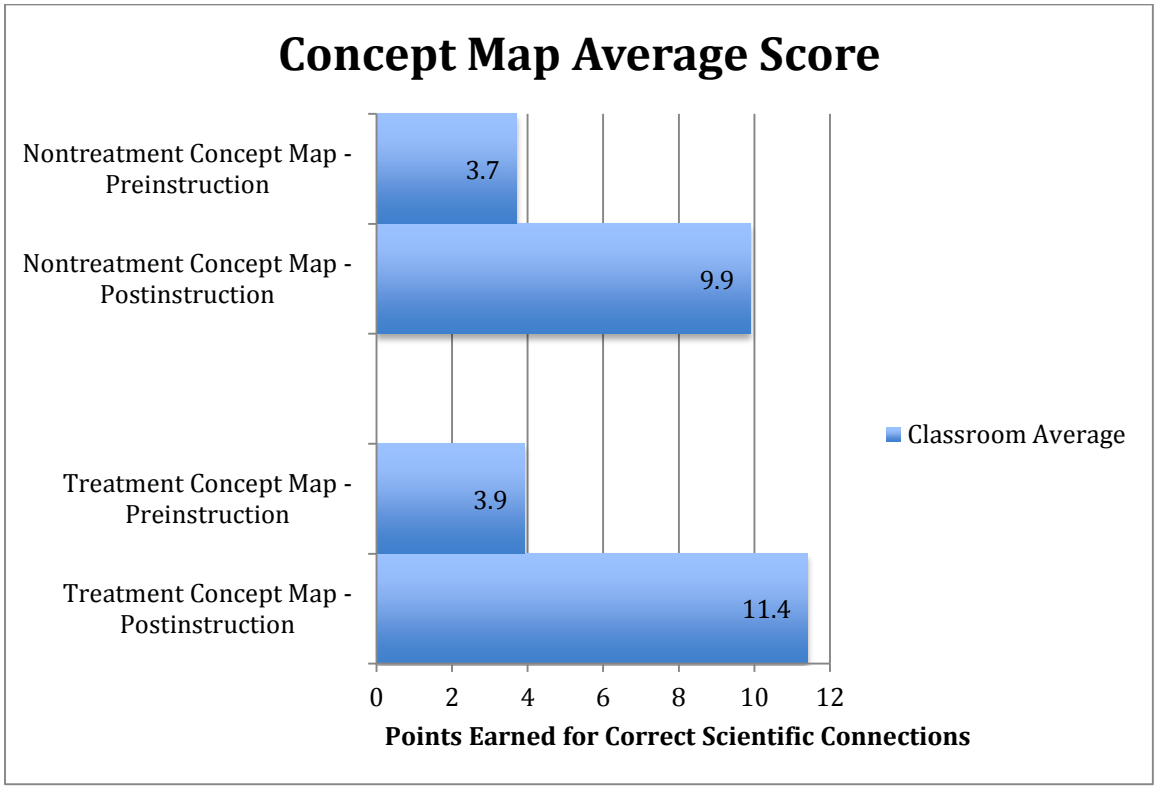


Figure 4. Concept Map Average Score, (non-treatment *N*=18, treatment *N*=20).

Classroom averages at the beginning and end of both non-treatment and treatment units show very similar growth patterns (Fig. 4). Even though there were three more

terms found on the physical science concept map than the earth science concept map, students were allowed to add additional terms on both concept maps to demonstrate their understanding. Samples of student concept maps are in Appendix K. Concept maps indicate that the $QPOE_2$ inquiry process develops a level of understanding similar to the non-treatment unit. Concept maps also support the theory that the inquiry process improves acquisition of core content knowledge that might not be uncovered or properly evaluated via traditional classroom assessments.

Data generated through the concept maps is also echoed by responses to student surveys. Students answered three Likert survey questions designed to assess their confidence in explaining the underlying science concepts both before and after participating in the $QPOE_2$ inquiry process. Table 2 presents student responses regarding the physical science concepts of heat, sound, and electric energy.

Table 2
Likert Survey Questions Probing Students' Understanding of Science Concepts

1 – Strongly Agree	2 – Agree	3 – Neutral	4 –Disagree	5 – Strongly Disagree
I could confidently explain heat energy to someone else.				
1 5.0%	1 5.0%	3 15.0%	5 25.0%	10 50.0%
6 27.3%	4 18.1%	7 31.8%	4 18.2%	1 4.5%
I could confidently explain sound energy to someone else.				
1 5.0%	1 5.0%	2 10.0%	4 20.0%	11 55.0%

7 31.8%	6 27.3%	6 27.3%	1 4.5%	2 9.0%
I could confidently explain electrical energy to someone else.				
2 10.0%	2 10.0%	7 35.0%	2 10.0%	6 30.0%
9 41.0%	6 27.3%	5 22.7%	0 0.0%	2 9.0%

Note. Light Grey – Pre instruction, Dark Grey – Post instruction, *(N*=22)

Only two students expressed a positive degree of confidence in explaining heat and sound energy before the treatment unit. Following the instructional intervention, 10 students felt a positive degree of confidence in explaining heat energy, and 13 students, more than half of the classroom, felt a positive degree of confidence in explaining sound energy. This trend was repeated in the results of the Likert survey question regarding electrical energy. While 4 students expressed confidence prior to the intervention, 15 students, 68.3%, expressed confidence following the intervention. This shift in confidence mirrors the shift experienced within the non-treatment unit survey questions, suggesting students are attuned to their understanding, and capable of assessing their level of confidence and confusion within the classroom. Through traditional teaching techniques as well as the inquiry process students were confident that they were acquiring the core scientific knowledge necessary to understand the main concepts found within each unit.

The Likert survey asked an open-ended question following each degree of confidence question. Students were asked what parts of each type of energy concept were still confusing. Thirteen of 22 students wrote the comment: “everything” is still

confusing with heat energy. Fourteen students (N=22) wrote that they were confused about "everything" involving sound energy. Students expressed their confusion regarding electrical energy with nine students (N=22) reporting that "everything" was confusing. The number of post-treatment comments stating that "nothing" was confusing was almost a reverse to the number who were confused about "everything" before the unit began. Out of 22 responses, 10 students reported that "nothing" was still confusing about sound energy. Nine students reported that "nothing" was still confusing about heat energy. And, 11 students reported that "nothing" was still confusing about electric energy.

More notable as an educator, however, is that by the end of the treatment unit student questions became very specific: How does heat energy burn you? How is heat energy made? Why can't we talk in space? How can sound reach our ears? How does electricity actually shock a person? These very specific questions demonstrate that students working through the $QPOE_2$ framework were indeed gaining content knowledge, and becoming more involved in building scientific understanding.

Teachers must ensure their students gain an understanding of fundamental science concepts. There is, however, another aspect of science education that is overlooked or not explicitly taught: the nature of science. Often in the pursuit of scientific knowledge acquisition, instruction in the nature of science is neglected. Students are not taught how scientists work to generate knowledge within their disciplines, or how that knowledge is built over time based on an accumulation of evidence. A sub question of this action research is what are the effects of using $QPOE_2$ on students' scientific argumentation and evaluative skills?

Students were asked three open-ended survey questions before and after their work with the $QPOE_2$ model of inquiry; "What is argumentation in science? Why is it important for scientists to present their evidence and conclusions to other scientists? What have you learned about science as a result of participating in the $QPOE_2$ inquiry process?

Fourth-grade students have been engaged in science instruction within their homeroom and a weekly elementary science lab experience since first grade, yet, in the pre-treatment survey, none of the 20 students were able to answer the question: what is argumentation in science? Seventeen wrote that they did not know how to define a scientific argument. Two students (N=20) provided no response, and one defined it as when students don't listen. Unpredictably, after three and a half years of science instruction, none of the students could identify this important aspect of the nature of science.

Using the $QPOE_2$ step book and scaffolded instruction from their teacher, students worked through three investigations during the treatment unit involving energy. At the end of this work, only seven of 22 students were still unable to articulate a definition of a scientific argument. Fifteen students provided some definition of scientific argumentation; eight correctly identified a scientific argument as a scientist or group of scientists discussing their claim(s) and fellow scientists discussing the validity of these claims, one wrote, it is "when one scientest [*sic*] says yes/no to another scientest [*sic*]." and six were able to make the connection that it involved scientists sharing their investigative results and/or reporting their work. Working through the QPOE2 inquiry

framework for nine weeks resulted in the majority of the classroom (68%) correctly identifying the "what" of scientific argumentation.

Similar gains in scientific argumentation and evaluative knowledge acquisition resulted from the $QPOE_2$ inquiry model as evidenced through responses to a second question. Prior to intervention, nine students (N=20) reported that they did not know why it was important for scientists to present their evidence and conclusions to other scientists, while two provided no response at all. Only six students (30%) correctly identified the purpose of scientific argumentation.

Table 3 presents the student survey responses both before and following instruction with the $QPOE_2$ inquiry model. After the treatment unit, sixteen students (73%) correctly identified at least one aspect of the importance of sharing results of investigations with others.

Table 3
Student Response to Classroom Survey Before/After $QPOE_2$ Treatment

Number of Students		Student Response to the Probe: Why is it Important for Scientists to Present Their Evidence and Conclusions to Other Scientists?
Before	After	
3	9	So other scientists can repeat their tests and prove their claims. *correct*
2	7	So other people know what they learned/tell new discoveries. *correct*
1	0	Help other scientists. *correct*
1	0	Don't keep repeating experiments on the same thing. *incorrect*
2	1	It's important. *incorrect*
9	4	I don't know. *incorrect*
2	1	No written response. *incorrect*

Note. (*N*=20-22)

In response to the third question probe that asked what the student learned as a result of participating in the $QPOE_2$ inquiry process, one student wrote he learned that "science changes the world." Another student who participated in the student interview process remarked that $QPOE_2$ "helped me learn how scientists do science." These are heartening responses. Student responses to the three "nature of science" questions demonstrated significant growth in understanding the role and importance of scientific argumentation.

Further support for this conclusion comes from instructor field observations. At the end of the first treatment unit, instructor and students analyzed classroom data, created a scientific claim, provided evidence from classroom data, and connected their claim and evidence. At the end of the second treatment unit, students worked in their

investigative partnerships to analyze their data, create a scientific claim, provide evidence from their data, and connect their claim and evidence. Time constraints allowed only four groups to present their scientific arguments to their peers. All groups struggled to present their evidence and claims, and peers struggled to engage in scientific argumentation. Questions asked by peer evaluators were limited to further explanations of investigative plans, feelings about their experiment, and further ideas for exploration.

Significant growth, however, occurred by the end of the third treatment unit. Students used data and notes from their science journals, and examples of science posters presented at conferences, to create a poster presentation of their investigations and scientific arguments. Over the course of two days, seven student groups presented their investigations to the class. Six of the seven groups presented a scientific claim, but only two groups supported their claim with evidence from data collection and observations without prompting from peers or the teacher. This was a bit disappointing, but the peer reviewers caught these omissions and asked presenters to provide evidence and arguments supporting their claim. While limited usable data was generated via peer evaluations, students did engage in scientific argumentation which I documented in my instructor field observations.

A sample scientific argument is documented below. Student A made the claim that a steel wire became hotter than a copper wire and caused balloons to pop sooner due to this difference in heat.

Student B: While you were conducting the test did you do two different things?
Student A: What do you mean?

Student B: Maybe it isn't the wires that caused the change, but maybe you did other things to cause this difference. Did you try two different size balloons or were they the same?
Student A: I made them the same.
Student C: What about the way you connected the wires?
Student A: I connected them the same.
Student D: Maybe you taped them to the balloon differently.
Student E: What about the thickness of the wires?
Student A: What?
Student E: Maybe the copper wire was thicker than the steel wire and this is why the steel wire heated up faster.
Student A: I taped them the same and they were the same thickness.

As an instructor I was astounded at the number of questions asked of Student A. Up to this moment students had never engaged in scientific argumentation. Through their work with the $QPOE_2$ step book and its prompting questions, students were now asking peer scientists to evaluate their controls and investigative procedures.

Two days later another student (Student M) presented her claim that she measured less energy with two lemons (one lemon cut in half but connected with zinc nails and a copper wire) than with one lemon. Student M had connected the lemons to four 1.5 V batteries. Other students had also experimented with changing the number of lemons and measured how much voltage adding lemons created. Her peers saw flaws in her methods and were ready to challenge her claim.

Student N: What was your highest measurement?
Student M: One lemon had 1.8 V. Two lemons had only 0.86 V.
Student N: Why would you need the batteries?
Student O: The lemons could have had no voltage and you could have been only measuring the batteries.
Student P: Did you test it without the batteries?
Student M: No.
Student Q: Did you have the batteries facing the correct way?
Student M draws the batteries on the board.
Student Q: I meant did you have the + and – facing the proper way.
Student M: I don't know.

Student R: What was your control?

Students were actively engaging each other in questioning scientific claims, data, and investigative methods, even though they weren't able to present strong scientific arguments or support their claims with evidence and reasoning. Teacher observations documents that students gained an understanding of scientific argumentation and improved their skills in evaluating scientific arguments.

Motivation, a desire to engage in the topic of instruction and learning, is a key factor in student and teacher success. How did the $QPOE_2$ inquiry model affect motivation for both students and instructor? I am passionate about science instruction and have worked as an elementary science specialist for six years continuously striving to improve my instructional methods. I enjoy teaching science more than any other subject and have participated in an Earthwatch research experience, attend the regional math and science update every year at Grand Valley State University, serve on the Kent Intermediate School District's Science Team, and am currently enrolled in the Master of Science in Science Education program through Montana State University.

Daily journal reflections document that the $QPOE_2$ inquiry model provided a positive motivational influence, but also exacted a toll due to various institutional factors. The positive motivational influences centered on the themes of student independence, nature of science instruction, and authenticity. Students were engaged in science. One of the darkest days in the treatment unit occurred on a Friday when students designed their own electricity experiments. A portion of Friday's journal reads, "What a horrific mess. Students' experiments aren't working, the multimeters aren't working, and students are

not acting like scientists." After a contemplative weekend, however, a rejuvenated teacher returned on Monday with a lesson and classroom discussion on "failed experiments." We discussed how in science we not only gain knowledge by achieving an expected result; we gain knowledge when something does not occur as expected (and sometimes the "failed" experiment yields more useful data than the one that worked). It was an authentic lesson in how making a mistake can lead to knowledge. A portion of the journal from that day records, "I often try to convince my students that they are not in school to get the right answer. It's important to remember that Friday was not a failure. Students learned this lesson in a more authentic way today."

My motivation increased as I saw student understanding of the nature of science increase during the last week. On April 28, 2015 I recorded in my journal, "I taught inquiry to my sixth-grade students in science lab every year. They never achieved this level of scientific argument. Think what would happen if students were engaged in this model from an earlier age." Finally, my motivation increased at the end of the treatment unit when quantitative data was collected that showed an increase in knowledge of scientific argumentation and student motivation.

Overall, even though I was motivated to teach with the $QPOE_2$ model, this inquiry model generated more negative journal entries than positive responses. The majority of these negative responses, however, were caused not by the inquiry model directly, but by institutional factors that made it difficult to teach with this model. There were many entries recording a concern that the inquiry model required a lot of time. On Friday, March 20, 2015 after students conducted heat experiments I recorded, "How can I

squeeze this type of instruction into my day? We spent over an hour and fifteen minutes just to set up, measure, and pack up our experiments." Again, on Friday, April 17, 2015 the journal reads, "What a horrific mess…. We spent over an hour on this project today."

Curricular demands in elementary school have put a squeeze on the amount of time allotted to science and social studies. This institutional demand created distress and worry for myself that the inquiry model was not providing enough specific science content. A majority of daily lessons required over an hour.

Student responses to a series of Likert survey questions at the beginning of the action research documented a positive view of science toward the weekly classroom laboratory experience and homeroom class instruction. A total of three Likert survey questions were asked regarding students' motivation and attitudes in the science classroom (Appendix L).

Students completed the same survey three more times: after the non-treatment unit, before the treatment unit, and after the treatment unit. Figure 5 documents the change in attitude and motivation over the course of this action research project. At the end of the treatment unit twice as many students reported they strongly agreed with the statement they look forward to science class in their homeroom. Another significant data point is the shift among students who reported feeling neutral or disagreed with that same statement. At the end of the non-treatment unit nine out of 20 (45%) students reported feeling neutral or disagreed with the statement that they looked forward to science in their classroom. At the end of the treatment unit only five students out of 22 students (23%)

remained neutral or disagreed with the statement that they looked forward to science in their classroom.

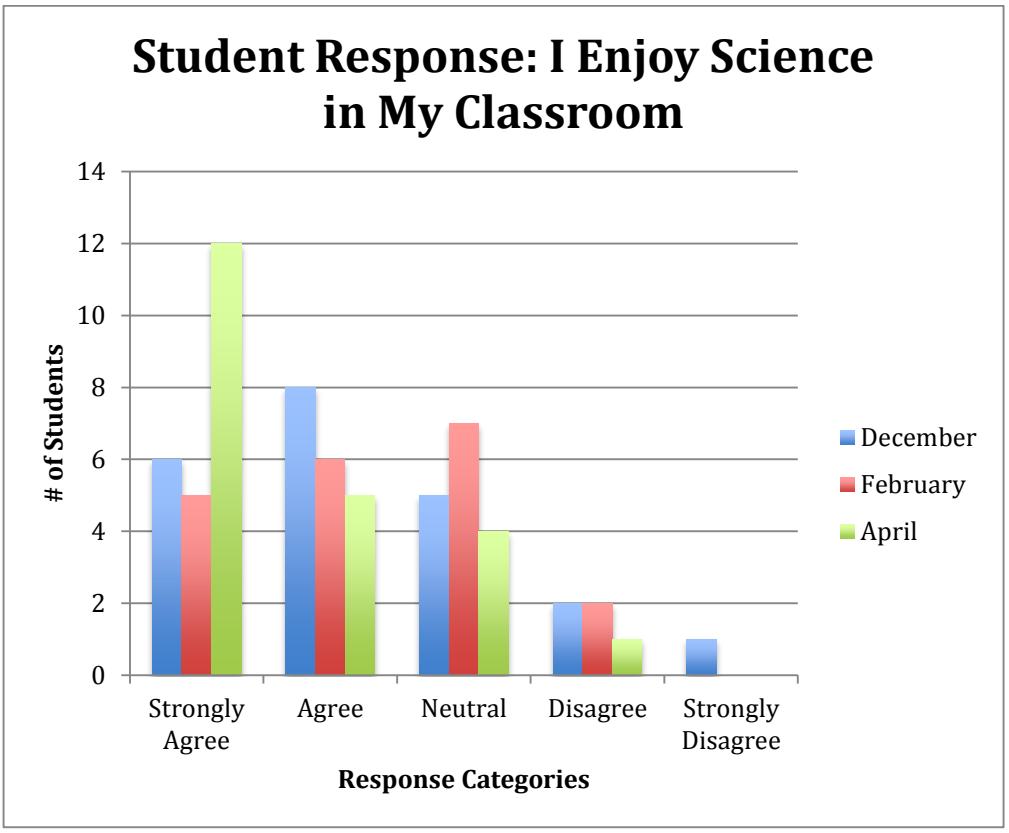


Figure 5. Likert Student Survey Response, (*N*=20-22).

By April only one student had a negative view of science within the classroom, suggesting the QPOE$_2$ inquiry model had a significant positive effect on the attitude and motivation of fourth-grade students within the classroom. Two common themes were identified through student interviews conducted following the treatment unit and document how the QPOE$_2$ framework helped shift student motivation and attitude. First, students reported that they were engaged in doing science and no longer felt like passive participants in what had gone before. Second, they were in charge of designing and

executing a scientific investigation without direct teacher involvement and this brought elements of agency, independence, and mystery to their work.

Follow-up and further open-ended inquiries regarding students' attitudes and motivations were made through the same survey. Elementary students in fourth-grade at East Elementary receive science instruction in both their classroom and once a week in an elementary science laboratory class. In response to why or why not students enjoy science lab and their classroom experience mid-way through the action research project student responses focused mainly on the idea of "fun". The final responses in the April survey reveal how the $QPOE_2$ inquiry model shifted student thinking from the "fun" of science to the "doing" of science. Table 4 documents major themes presented in the April survey.

Table 4
Student Response to Classroom Survey after $QPOE_2$ Treatment - Attitude and Motivation in the Science Classroom

Number of Students	Student Response to the Probe: I look forward to science class in my homeroom. Why or why not?
7	Making projects/experiments
5	Fun
3	Learn new things

Note. (*N*=22)

Another theme identified through these open-ended questions revealed that students had a difficult time identifying how they learn science best. The most common answer to this question in the December survey invoked a response involving watching videos and/or the teacher. Nine of 22 students reported that this was the way they learned

science best. In contrast only three out of 22 students identified that "hands-on" or "doing" science helped them learn science the best.

Data compiled in the final April survey documented a profound shift in students' understanding of how they learn science. Figure 6 highlights this shift away from "watching" to eight other learning categories. Of significance is the self-identification of 15 out of the 22 students that some type of "hands-on" activity helped them learn science the best.

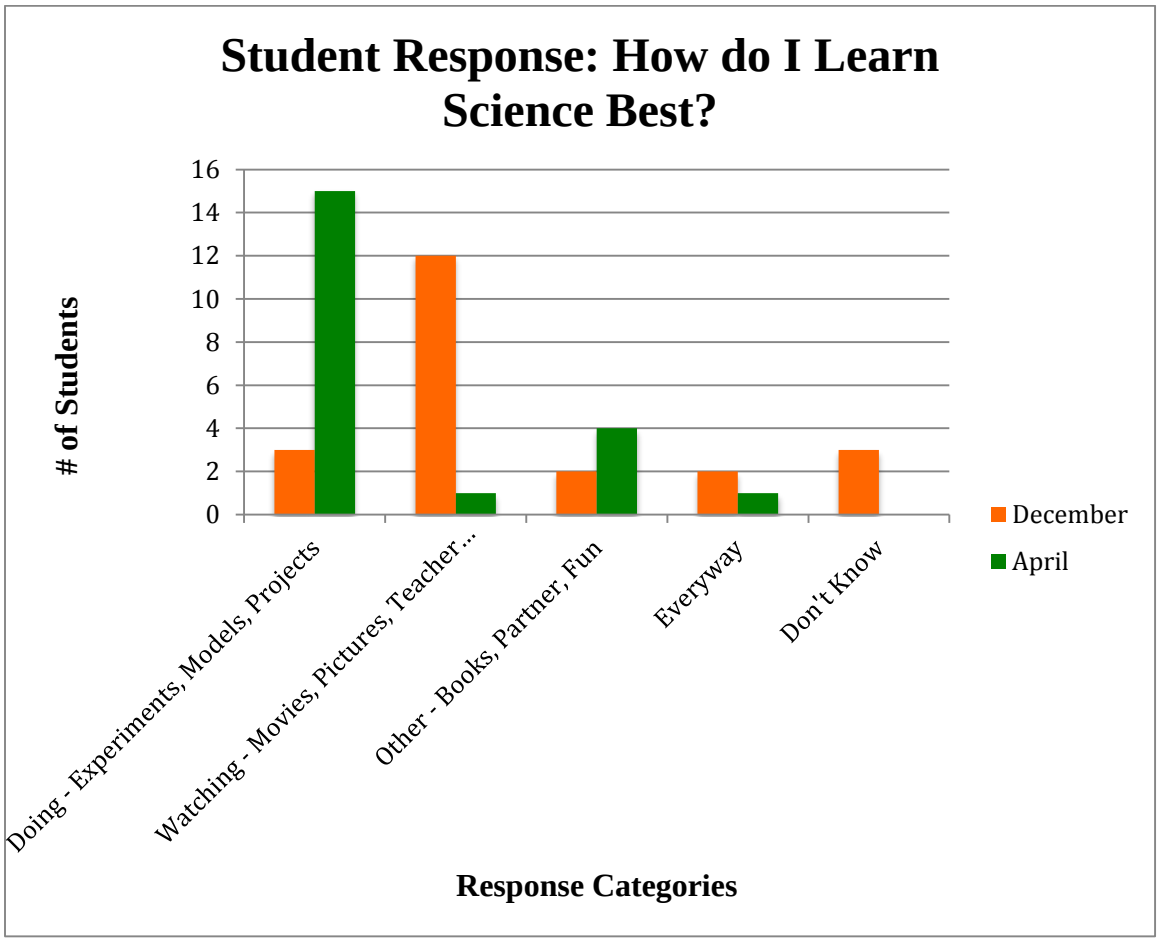


Figure 6. Question Probe Student survey – December and April results (*N*=21-22).

Student thinking was changing through their work with the QPOE2 framework, and they were becoming more aware of themselves as participants in the scientific process. Science was opened and revealed to them as an active process, and they began to see themselves as integral to that process and no longer "passive learners." "Doing" was how they saw themselves learning science after the treatment intervention.

This shift in awareness was also evident through comments made during individual student interviews. In interviews conducted in January the response to the question "when are you most motivated to participate in science?" elicited confused responses. One student replied that he didn't really know. Another student reported that she was most motivated to participate in science right after lunch.

The individual responses to this prompt changed greatly during and following work within the $QPOE_2$ framework. Following the second treatment unit the same student who reported that he didn't know when he was most motivated to learn science responded, "It is when we are doing experiments. Experiments are fun." Another student replied that he was most motivated to participate in science when doing experiments. He mentioned that it was through testing and having things go wrong that excited him. "It is the mystery part I love most."

By the end of the final treatment unit, one common theme among the student interview group was articulated awareness that they were most motivated to learn science when they did experiments. "We get to do it. We aren't told what to do." Another student reported that it was the experiments that motivated her to participate in science. This student exclaimed, "Experiments help me learn. I feel like I'm doing science."

INTERPRETATION AND CONCLUSION

The goal of this action research project was to measure the impact of a local science research institute's model of science inquiry within an elementary classroom. The data compiled within my fourth-grade classroom verified many findings documented within science education research. In response to the two sub questions regarding student and teacher motivation, the Van Andel Education Institute's model of inquiry, $QPOE_2$, had a positive impact on both student motivation to participate and learn in the science classroom and the teacher's motivation to instruct with this model of inquiry.

At the end of the treatment unit themes mentioned in student interviews by different individuals expressed the importance of individual creativity, authenticity, and agency. Students had a personal investment in the scientific process that was created through the $QPOE_2$ inquiry model. One of the students, who received educational support services, said that the $QPOE_2$ process allowed him to "learn how to be a scientist." This was echoed by another student interviewed who said, "$QPOE_2$ is good. It makes me feel like a scientist."

One of the top-performing students responded to the question about how she felt about science that week with the following quote: "I liked making the experiment and poster. We didn't know what was going to happen. Most things we do in school the teacher already knows what is going to happen." Another student, who designed an experiment comparing the amount of electricity generated by different types of soda, commented at the end of the treatment, "It felt great. I learned more. Maybe it is just a

beverage but who knows what we can learn from it." $QPOE_2$ "helped me do new things. I was excited because we didn't get to do experiments last year."

Students recognized that even though they were designing experiments within a limited framework, as directed by the classroom teacher, they were in charge. They had a feeling of discovery, individual ownership, and authenticity. Everyone had a prediction, but no one knew what the outcome would be. This inquiry model left only one student out of 22 at the end of the treatment unit reporting a negative feeling regarding science within the classroom, while 77.3 % reported a positive feeling regarding science within the classroom. The number of students who reported that they "strongly agreed" with the statement that they look forward to science class within their homeroom increased by 50% from December to April.

In response to the sub question on how the $QPOE_2$ framework affects the ability of elementary students to engage in scientific argumentation, the student's ability to present and evaluate a scientific argument showed significant improvement following the treatment unit. After three and a half years of direct science instruction, none of the 20 students could provide a definition or an idea that would explain the concept of a scientific argument. While students only demonstrated a basic level of competence in making and evaluating scientific arguments, they did show increased awareness of scientific argumentation and demonstrated this awareness through their actions. Following the three treatment units, 15 out of 22 students were able to provide either a correct or partially correct definition of a scientific argument.

More importantly students began to act like scientists during the poster presentations; asking presenters questions about procedures, data claims, controls and variables, and reasoning. Seven groups, 15 out of 23 students, were able to present their investigations and scientific arguments during the last treatment week. In every presentation a peer asked the presenter at least one question regarding their claim, evidence, or reasoning. In four of these presentations peers asked more than four questions that directly related to the scientific argument being presented.

While the Van Andel Education Institute's model of scientific inquiry demonstrated positive outcomes in understanding the nature of science and student/teacher motivation, results of the general science educational outcomes showed lower than expected improvement. Institutional limits to its incorporation within the current elementary classroom had an affect on final student assessment scores. Pre and post instructional assessments during the non-treatment and treatment units indicate an increase in scientific understanding for both methods tested, however, the increase in scientific understanding under the $QPOE_2$ model was not as significant as traditional methods. Average post assessment scores for non-treatment units increased 43.8%, while treatment unit scores only increased by 35.9% compared to pre test scores. Students scored 1.5 times higher following the traditional instructional model than they did with the $QPOE_2$ framework model; only two of 21 students scored lower than 50% on the non-treatment unit final assessment, while 11 of 23 students scored lower than 50% on the treatment unit final assessment.

While pre and post assessment data suggest the $QPOE_2$ model is less effective than traditional methods, there were outside variables that could have negatively influenced implementation of the QPOE2 model. These variables include disparate assessments, poor instruction, and institutional time pressures. East Elementary School has an elementary science specialist who supplements the classroom curriculum with activities and projects that are difficult for the classroom teacher to facilitate. Students within fourth-grade participate in this science class once a week for 45 minutes per session. The assessment for the energy unit had been traditionally given within this laboratory class period and included an electricity performance assessment. Three years ago the state legislature changed the teacher evaluation system in Michigan, and the elementary science specialists redesigned the energy assessment for this year. The test was given on student Chromebooks, and multiple-choice questions were given through a Google Form on each student's Chromebook. This was the first time an assessment was given in this manner and could be part of the reason scores were lower.

Institutional time pressures and a lack of instructional familiarity by both the teacher and the students could have been contributing factors to the lower overall improvement. Students had no previous experience with a complete inquiry model of science instruction and I had no experience with implementing it in a classroom. This required that 10-15 minutes of every classroom instructional time involved learning about the $QPOE_2$ framework. While this reaped many benefits in the growth of student understanding of the nature of science, it required a sacrifice in the amount of scaffolded instruction. The large blocks of time held exclusively for mathematic and language arts

instruction in the daily elementary schedule imposed further institutional time limits on science instruction.

Research demonstrates that this scaffolding of science content within an inquiry framework is essential for students to learn (Mayer, 2004). Building upon this research the NGSS (2013) calls for the integration of science practices and content to build meaning for students. Instructing within the $QPOE_2$ framework required blocks of instructional time within the fourth-grade classroom that often extended over an hour. A lack of familiarity with the $QPOE_2$ framework by both the teacher and students caused the model to be integrated in the fourth-grade classroom more as a stand-alone model of the nature of science instruction. This concern was reported in my daily journal on numerous occasions. I was not able to integrate more science content within this framework and this concern was born out in student final assessment scores. Greater familiarity with the $QPOE_2$ model of inquiry by both the teacher and students would allow more time to be spent on content acquisition, hopefully leading to higher final assessment scores.

VALUE

Results of this action research project provide caution and cause for celebration. There are concerns involved in incorporating the $QPOE_2$ framework within the elementary science classroom. The $QPOE_2$ framework requires large blocks of time both for instruction in the framework and in the investigation cycle itself. As both the teacher and students become familiar engaging in scientific inquiry within this $QPOE_2$ model less instructional time would be taken up by teaching the framework. This would free more

time for engagement in an investigation and building direct science content knowledge. In the end, these investigations would still cause time pressures due to the nature of the time required for the rest of the elementary core curriculum.

Conducting investigations requires a lot of time, space and materials. The electricity investigations designed by my fourth-grade classroom required batteries, nails, copper wire, multimeters, thermometers, wire strippers, lemons, potatoes, balloons, steel wool, light bulbs, light bulb holders, and alligator clips. Some of these items were available through our elementary science specialists. Many elementary schools would not have these supplies available for a classroom teacher. Researching and ordering supplies can be time consuming and expensive, both of which can be barriers to implementation of the $QPOE_2$ inquiry model. However, results of this project have shown the extra time and money can result in improvements in student knowledge and involvement. Data in this action research project documents the growth in students' attitudes and motivation for science and their increased knowledge in the nature of science. Students articulated through their surveys and interviews that the $QPOE_2$ model of inquiry made them feel like scientists. They were involved in a "mystery" even I didn't know the outcome of their investigations. This sense of authenticity and individual ownership produced a powerful, and unexpected, shift in students' attitudes toward science in their classroom. Six out of 22 students reported a strong positive motivation for science within their homeroom prior to the treatment intervention. Grandville Public Schools has worked hard to support science instruction within its elementary schools, and students are generally excited about science and their work in the elementary science

laboratory special. Incorporating the $QPOE_2$ framework of inquiry reinforced this positive trend for elementary science. At the end of three inquiry cycles the number of students strongly agreeing that they looked forward to science within their classroom had doubled. Only one student out of 22 reported a negative feeling toward science within the classroom.

In a district science committee meeting on April 16, 2015, the assistant high school principal reported that students struggle and achieve only average scores on the statewide science assessment. At the middle and high school level, students' scores on different underlying science concepts are often higher than questions involving the "how" of science. With a short exposure to the $QPOE_2$ model of inquiry, my fourth-grade students progressed from none being able to define scientific argumentation to 15 of 20 students being able to articulate some aspect of scientific argumentation. More importantly, students progressed in their nature of science knowledge. In the classroom presentations at the end of the last investigative cycle every presentation was challenged with at least one question pointedly addressing their claim, evidence, or reasoning. Students were asking about controls, variables, degree of confidence, and offering up alternative explanations for the claims being made by their scientific peers.

The strength of the $QPOE_2$ model of scientific inquiry lies in support for the students and teacher. Each page within the step book or app provides the definition of the inquiry stage, its purpose, and a series of questions that teacher and student can use to assess student performance in this area of the inquiry cycle. One of the difficulties experienced by elementary teachers is having a resource for teaching these "nature of

science" principles and then having a framework within which to evaluate student performance.

The $QPOE_2$ framework for inquiry is an effective tool for incorporating inquiry education within the elementary science classroom. Data from this study, however, cautions teachers to scaffold instruction. Inquiry by itself will not instruct students in the underlying scientific principles being studied. If $QPOE_2$ is not scaffolded it becomes solely a method of teaching the nature of science, or worse, a pure method of discovery science. Despite this caution and barriers to incorporation, $QPOE_2$ has a positive impact on student attitudes and motivation toward science in school. It also increases student understanding of scientific argumentation and the nature of science. It is an encouraging moment for a teacher when a student remarks, "$QPOE_2$ is good. It makes me feel like a scientist." This is motivation for the classroom teacher to continue examining practices which engender these powerful feelings in students while finding a more effective way to scaffold science instruction within this framework.

REFERENCES CITED

Abell, S. K., & Smith, D. C. (1994). What is science?: Preservice elementary teachers' conceptions of the nature of science. *International Journal of Science Education, 16*(4), 475-487.

Anderson, R. D. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education*. *13*(1), 1-12.

Biggers, M. & Forbes, C. T. (2012). Balancing teacher and student roles in elementary classrooms: Preservice elementary teachers' learning about the inquiry continuum. *International Journal of Science Education, 34*(14), 2205-2229.

Bishop, M., Burns, M., Coon, M., Cramer, R., Jacques, M., Johnson, C., Nicolette, J., & Schregardus, R. (2011). *Level 1 QPOE$_2$ investigation organizer step book: Questions, prediction, observation, explanation, evaluation*. Grand Rapids, MI: Van Andel Education Institute.

Bybee, R., Taylor, J., Gardner, A., Van Scotter, P., Carson Powell, J., Westbrook, A., Landes, N. (2006) *The BSCS 5E instructional model: origins, effectiveness, and applications*. Colorado Springs: BSCS. Retrieved from http://science.education.nih.gov/houseofreps.nsf/b82d55fa138783c2852572c9004f5566/$FILE/Appendix%20D.pdf

Davis, E. A., & Smithey, J. (2009). Beginning teachers moving toward effective elementary science teaching. *Science Education, 93*(4), 745-770.

Dewey, J. (1897). *My pedagogic creed*. Retrieved from http://en.wikisource.org/wiki/My_Pedagogic_Creed

Fulton, L., & Poeltler, E. (2013). Developing a scientific argument: modeling and practice help students build skills in oral and written discourse. *Science and Children, 50*(9), 30-35.

Geier, R., Blumenfeld, P. C., Marx, R. W., Krajcik, J. S., Fishman, B., Soloway, E., & Clay-Chambers, J. (2007). Standardized test outcomes for students engaged in inquiry-based science curricula in the context of urban reform. *Journal of Research in Science Teaching, 45*(8), 922-939.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics, 66*(1), 64-74.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist, 42*(2), 99-107.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, *41*(2), 75-86.

Lederman, N.G., Lederman, J.S., & Antink, A. (2013). Nature of science and scientific inquiry as contexts for the learning of science and achievement of scientific literacy. *International Journal of Education in Mathematics, Science, and Technology*, *1*(3), 138-147.

Mayer, R. E. (2004). Should there be a three-strike rule against pure discovery learning? *American Psychologist*. *59*(1), 14-19.

Mills, G. E. (2014). *Action research: A guide for the teacher researcher* (5th ed.). Boston: Pearson.

Minner, D. D., Levy, A. J., & Century, J. (2009). Inquiry-based science instruction-what it is and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching*, *47*(4), 474-496.

National Research Council. (1996). *National science education standards*. Washington D.C.: National Research Council.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington D.C.: The National Academies Press.

Next Generation Science Standards. (2013). *Appendix b: Responses to public drafts* [PDF file]. Retrieved from http://www.nextgenscience.org/sites/ngss/files/Appendix%20B%20-%20Responses%20to%20the%20Public%20Drafts.pdf

Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching, 41*(10), 994-1020.

Osborne, J. (2010). Arguing to learn in science: The role of collaborative, critical discourse. *Science 328*, 463-466.

Palmer, D. H., (2009). Student interest generated during an inquiry skills lesson. *Journal of Research in Science Teaching, 46*(2), 147-165.

Pickens, M. & Eick, C. J. (2009). Studying motivational strategies used by two teachers in differently tracked science courses. *Journal of Educational Research. 102*(5), 349-359.

$QPOE_2$ Investigation Organizer for Scientific Inquiry [online image]. Van Andel Education Institute. Retrieved December 5, 2014 from http://www.vai.org/en/vaei/scienceacademy/products/Posters.aspx

Skinner, E. A., & Belmont, M. J. (1993). Motivation in the classroom: Reciprocal effects of teacher behavior and student engagement across the school year. *Journal of Educational Psychology*, *85*(4), 571-581.

Triezenberg, S. (2014). *Message from the director*. Retrieved from http://www.vai.org/en/vaei/about/message-from-the-director

Vanides, J., Yin, Y., Tomita, M., & Ruiz-Primo, M. A. (Summer 2005). Using concept maps in the science classroom. *Science Scope, 8.* Retrieved from http://web.stanford.edu/dept/SUSE/SEAL/Reports_Papers/Vanides_CM.pdf

Wilson, C., Taylor, J., Kowalski, S., & Carlson, J., (2010). The relative effects and equity of inquiry-based and commonplace science teaching on students' knowledge, reasoning, and argumentation. *Journal of Research in Science Teaching, 47*(3), 276-301.

Windschitl, M., Thompson, J., & Braaten, M. (2008). Beyond the scientific method: Model-based inquiry as a new paradigm of preference for school science investigations. *Science Edition, 92*(5), 941-967.

APPENDICES

APPENDIX A

$QPOE_2$ GRAPHICAL REPRESENTATION OF THE SCIENCE INQUIRY MODEL



Figure 7. $QPOE_2$ Investigation Organizer for Scientific Inquiry [online image]. Retrieved December 5, 2014 from http://www.vai.org/en/vaei/science-academy/products/Posters.aspx

APPENDIX B

SAMPLE QPOE2 STEP BOOK PAGE

Explanation*

What Did I Learn?

Definition: Stating my **claim** using my **evidence** and **reasoning.**

Claim Definition:
My claim answers my investigation question. It tells what I learned from my investigation.

Evidence Definition:
My evidence is the scientific data I use to support my claim.

Scientific data is data (information) I collect through my investigations or from other scientists' data.

Reasoning Definition:
Reasoning tells why the data I used is evidence that supports my claim. Reasoning is my argument. A strong argument includes:

- what I already know
- how my investigation was a fair test
- science words and ideas
- ideas, evidence, and arguments of other people

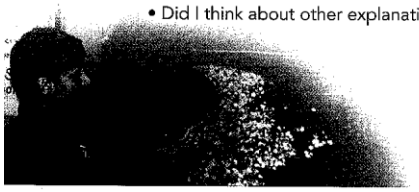
Purpose: To make sense of what I observed so I can tell others why they should accept my claim.

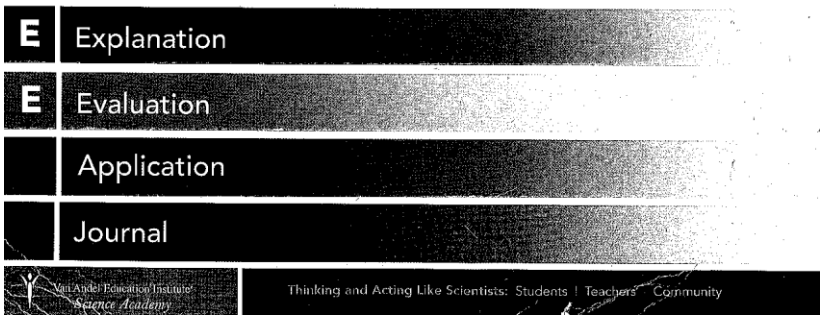
Evaluating My Explanation: *(6 point example)*

Claim:
- Does my claim answer my investigation question? *(1 point)*

Evidence:
- Does the evidence I used support my claim? *(1 point)*

Reasoning:
- Does my reasoning connect my claim and my evidence? *(1 point)*
- Does my reasoning tell why my evidence supports my claim? *(1 point)*
- Have I made a strong argument? *(1 point)*
- Did I think about other explanations? *(1 point)*





Bishop, M., Burns, M., Coon, M., Cramer, R., Jacques, M., Johnson, C., Nicolette, J., & Schregardus, R. (2011). *Level 1 QPOE$_2$ investigation organizer step book: Questions, prediction, observation, explanation, evaluation*. Grand Rapids, MI: Van Andel Education Institute.

APPENDIX C

ORIGINS AND DEVELOPMENT OF INSTRUCTIONAL MODELS

Table 5
Origins and Development of Instructional Models

Historical Models		
Herbart *(Early 1900s)*	**Dewey** *(Circa 1930s)*	**Heiss, Obourn, and Hoffman** *(Circa 1950s)*
Preparation	Sensing Perplexing Situations	Exploring the Unit
Presentation	Clarifying the Problem	Experience Getting
Generalization	Formulating a Tentative Hypothesis	Organization of Learning
Application	Testing the Hypothesis	Application of Learning
	Revising Rigorous Tests	
	Acting on the Solution	



Contemporary Models	
Atking and Karplus *(1960s)*	**BSCS 5E** *(1980s)*
	Engagement
Exploration ---------->	Exploration
Invention (term introduction) ---------->	Explanation
Discovery ---------->	Elaboration
	Evaluation

Bybee, R., Taylor, J., Gardner, A., Van Scotter, P., Carson Powell, J., Westbrook, A., Landes, N. (2006) *The BSCS 5E instructional model: origins, effectiveness, and applications*. Colorado Springs: BSCS. Retrieved from http://science.education.nih.gov/houseofreps.nsf/b82d55fa138783c2852572c9004f5566/$FILE/Appendix%20D.pdf

APPENDIX D

BSCS 5E INSTRUCTIONAL MODEL

Table 6
Summary of the BSCS 5E Instructional Model

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

Bybee, R., Taylor, J., Gardner, A., Van Scotter, P., Carson Powell, J., Westbrook, A., Landes, N. (2006) *The BSCS 5E instructional model: origins, effectiveness, and applications*. Colorado Springs: BSCS. Retrieved from http://science.education.nih.gov/houseofreps.nsf/b82d55fa138783c2852572c9004f5566/$FILE/Appendix%20D.pdf

APPENDIX E

PRE AND POST UNIT STUDENT SURVEY 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.

Please circle the response that most closely describes how you feel.
1 – strongly agree
2 – agree
3 – neutral
4 – disagree
5 – strongly disagree

I look forward to elementary science lab class.

1 2 3 4 5

Why or why not?

I look forward to science class in my homeroom.

1 2 3 4 5

Why or why not?

I enjoy reading about science.

1 2 3 4 5

What have you read that you have enjoyed?

I enjoy conducting investigations in science.

1 2 3 4 5

(Pre and Post Non-treatment Unit Questions)

I could confidently explain the rock cycle to someone else.

1 2 3 4 5

What parts are still confusing?

I could confidently explain how to identify minerals to someone else.

1 2 3 4 5

What parts are still confusing?

I could confidently explain what an earth's natural resource is to someone else.

1 2 3 4 5

What parts are still confusing?

(Pre and Post Treatment Unit Questions)
I understand the concept of energy.

1 2 3 4 5

I could confidently explain heat energy to someone else.

1 2 3 4 5

What parts are still confusing?

I could confidently explain sound energy to someone else.

1 2 3 4 5

What parts are still confusing?
I could confidently explain electrical energy to someone else.

1 2 3 4 5

What parts are still confusing?

Please answer the following questions as honestly as possible. Your responses will be used to help me understand how you are thinking and learning. I will not use your responses for a grade, but I will use your responses to help me improve as your science teacher.

1. How do you learn science best?

2. When do you enjoy science the most?

   least?

3. What is argumentation in science?

4. Why is it important for scientists to present their evidence and conclusions to other scientists?

5. What have you learned about science as a result of participating in the inquiry process ($QPOE_2$)?

6. Has participating in the inquiry process ($QPOE_2$) changed the way you feel about science in school?

7. Is there anything else you would like to say about the inquiry process ($QPOE_2$)? Please explain your thoughts.

APPENDIX F

PRE AND POST UNIT 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. How do you feel about science at school? Explain.

2. How did you feel about science this week? Explain.

3. When are you most motivated to learn/participate in science? Explain.

4. *Non-treatment Unit*: How did participating in the (rock collection, mineral testing, natural resource book) project help you understand the science concept?

4. *Treatment Unit*: How did creating an investigation of (heat, sound, electric energy) help you understand the scientific concept?

5. *Non-treatment Unit*: How did you feel about participating in the (rock collection, mineral testing, natural resource book)? Explain your answer.

5. *Treatment Unit*: How did you feel about creating an investigation to understand (heat, sound, electric energy)? Explain your answer.

6. Explain your concept map to me in your own words.

7. Please place the following term in your concept map and explain your thinking
   Non-treatment Unit: Paper

   Treatment Unit: Wavelength

8. Is there anything else you would like to share with me regarding this project and/or science?

APPENDIX G

CONCEPT MAPS: NON-TREATMENT AND TREATMENT

Create an earth science concept map using the words provided as a base. Begin your concept map with the main topic of our unit of study. This word is found in **bold** face type. Use the remaining words to show your connections of understanding. You may add your own words and examples to help explain your connections, but you must include the terms found in the box. Please add connecting words and provide your own examples to support your connections. Remember your concept map is not part of your grade. Rather, its construction helps me to understand what you are learning and what connections you are making to the ideas presented in class.

Earth		
Mineral	Rock	Renewable
Nonrenewable	Natural Resource	Igneous
Sedimentary	Metamorphic	Identification

Create an energy concept map using the words provided as a base. Begin your concept map with the main topic of our unit of study. This word is found in **bold** face type. Use the remaining words to show your connections of understanding. You may add your own words and examples to help explain your connections, but you must include the terms found in the box. Please add connecting words and provide your own examples to support your connections. Remember your concept map is not part of your grade. Rather, its construction helps me to understand what you are learning and what connections you are making to the ideas presented in class.

Energy		
Sound	Simple	Heat
Circuit	Volume	Electrons
Parallel	Charge	Atoms
Pitch	Resistance	Molecules

APPENDIX H

CONCEPT MAP RUBRIC

Student concept maps were assessed based upon two main criteria: map complexity and quality of interconnected terms. Students who had achieved a high degree of proficiency created concept maps with a high degree of complexity – multiple connections were made among multiple terms. Students who had not achieved a high degree of proficiency created simpler concept maps. Simple concept maps often appear as a linear map, a simple branching tree, or a hub and spoke shape. The degree of complexity was analyzed and scored on a three-point rubric.

Map Complexity

0	Low degree of complexity
1	Average degree of complexity
2	High degree of complexity

The quality of interconnected terms was also analyzed and assigned a score based on a three-point rubric. Each connection was highlighted in a given color to aid in the scoring process. The total number of points generated through correctly interconnected terms was calculated and transferred to an Excel spreadsheet for each student.

Interconnected Terms

0	Wrong scientifically (yellow)
1	Weak connection scientifically (blue)
2	Scientifically correct (green)

Vanides, J., Yin, Y., Tomita, M., & Ruiz-Primo, M. A. (Summer 2005). Using concept maps in the science classroom. *Science Scope*, *8.* Retrieved from http://web.stanford.edu/dept/SUSE/SEAL/Reports_Papers/Vanides_CM.pdf

APPENDIX I

CAPSTONE TRIMEFRAME

January - 3 weeks	Rock Cycle
January/February – 2 weeks	Mineral Identification
February/March – 4 weeks	Renewable and Nonrenewable Natural Resources
March – 2 weeks	Heat Energy
March/April – 2 weeks	Sound Energy
April – 3 weeks	Electric Energy

APPENDIX J

INSTITUTIONAL REVIEW BOARD EXEMPTION

MONTANA
STATE UNIVERSITY

INSTITUTIONAL REVIEW BOARD

For the Protection of Human Subjects
FWA 00000165

960 Technology Blvd. Room 127
c/o Immunology & Infectious Diseases
Montana State University
Bozeman, MT 59718
Telephone: 406-994-6783
FAX: 406-994-4303
E-mail: cherylj@montana.edu

Chair: Mark Quinn
406-994-5721
mquinn@montana.edu
Administrator:
Cheryl Johnson
406-994-6783
cherylj@montana.edu

MEMORANDUM

TO: Brian Matthew Staggs and Walt Woolbaugh

FROM: Mark Quinn, Chair Mark Quinn MJ

DATE: December 4, 2014

RE: *"Using the Van Andel Education Institute's Model of Scientific Inquiry, QPOE$_2$, in the Fourth-Grade Classroom"* [BS120414-EX]

The above research, described in your submission of December 4, 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.

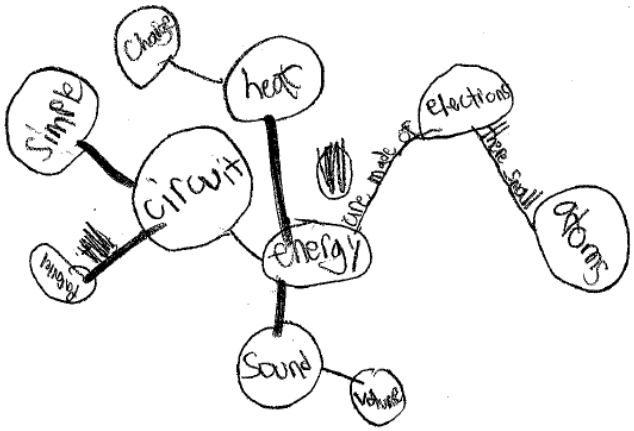
APPENDIX K

SAMPLE STUDENT CONCEPT MAPS

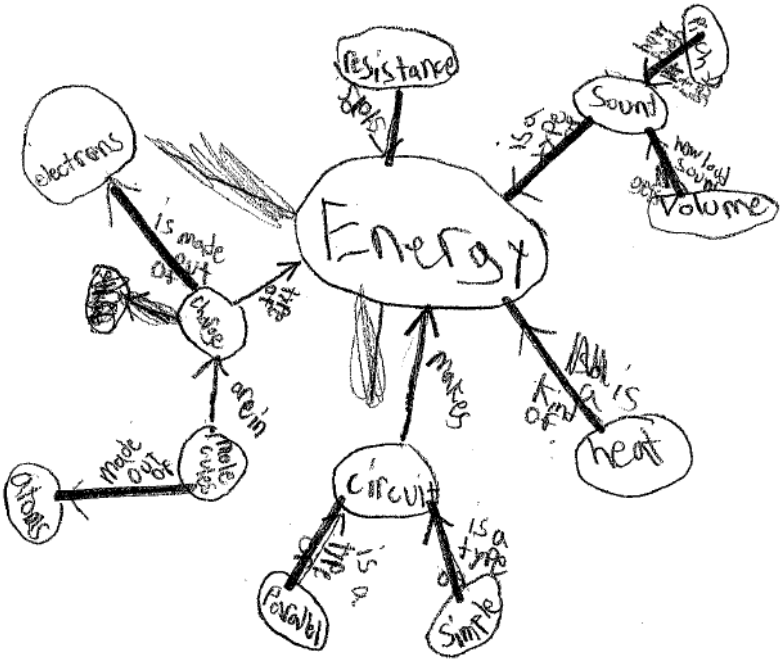
Appendix K

Sample Student Concept Maps

Preinstruction Concept Map Treatment Unit



Postinstruction Concept Map Treatment Unit



APPENDIX L

LIKERT SURVEY RESULTS STUDENT ATTITUDES AND MOTIVATION

Table 7
Likert Survey Questions Probing Students' Attitudes and Motivation in the Science Classroom in December

Question	1 – Strongly Agree	2 – Agree	3 – Neutral	4 –Disagree	5 – Strongly Disagree
I look forward to elementary science lab class.	11 50.0%	2 9.1%	7 31.8%	2 9.1%	0 0.0%
I look forward to science class in my homeroom.	6 27.2%	8 36.4%	5 22.7%	2 9.1%	1 4.5%
I enjoy conducting investigations in science.	9 40.1%	7 31.8%	5 22.7%	1 4.5%	0 0.0%

Note. (N=22).