Summer 2019

Using an Argument Driven Inquiry Model to Develop Scientific Proficiency in the Middle School Classroom

Lorelei Ross

USING AN ARGUMENT DRIVEN INQUIRY MODEL TO DEVELOP SCIENTIFIC PROFICIENCY IN THE MIDDLE SCHOOL CLASSROOM

by

Lorelei Ross

Bachelor of Science
University of Findlay, 2000

Master of Education
University of Toledo, 2002

Submitted in Partial Fulfillment of the Requirements

For the Degree of Doctor of Education in

Curriculum and Instruction

College of Education

University of South Carolina

2019

Accepted by:

James Kirylo. Major Professor

Janie Goodman, Committee Member

Leigh D'Amico, Committee Member

Rhonda Jeffries, Committee Member

Cheryl L. Addy, Vice Provost and Dean of the Graduate School

DEDICATION

This work is dedicated to my husband, daughter, and my parents. I want to thank my husband for encouraging me to start this journey and helping me see it to the end. Thank you for believing in me. Thank you for giving me the time and space that I needed to complete this. I want to thank my young daughter for her patience with me for all the time I spent away from her and seeing the importance of education and sticking through with something. I want to thank my parents for always being there for me and supporting me through my entire educational experience. Thank you to each one of you for helping me reach my goal.

ACKNOWLEDGEMENTS

I would like to thank my chair, Dr. Kirylo, for his guidance in this journey. His help, advice, suggestions, and support were instrumental in writing this work. Thank you to the other members of my committee, Dr. Janie Goodman, Dr. Rhonda Jeffries, and Dr. Leigh D'Amico for their time and input during the completion of this dissertation. Next, I would like to thank my colleagues who provided support, especially Amy Rossett, Leonardo Francisco, Emily Poeppelman-Adair, Tabatha Arce, Cam Norwood, and David Helms. I would also like to thank my co-worker and friend, Jennifer McGinnis for her friendship, advice, and support over the past three years. Finally, I would like to thank my best friend Dawn Thomas for all the phone calls, conversations, and discussions about my classwork.

ABSTRACT

The purpose of this study was to examine the impact of argument driven inquiry (ADI) on the development of evidence-based arguments for eight eighth-grade students. This study took place in the third quarter of the 2018-2019 school year. The setting was a public middle school in a suburban county in the Southeast. Through the use of an action research design, qualitative and quantitative data was collected over a six-week period using various instruments. Instruments included a content pretest and posttest, generating an evidence-based argument pre-test and post-test, pre- and post-formal interviews, pre and post science questionnaire Likert attitudinal scale, collection of artifacts, and field notes. The results revealed that ADI helped students with their development of evidence-based arguments.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADI………………………………………………………………..Argument-Driven Inquiry

NGSS………………………………………………… Next Generation Science Standard

NOS………………………………………………………………………..Nature of Science

CHAPTER ONE

INTRODUCTION

Contemporary science education reform has its roots in the 1983 document called *A Nation at Risk* (National Commission on Excellence in Education, 1983). This publication discussed the potential impact on the economic and societal problems associated with a failed education system. In the document, it was noted, "We are raising a new generation of Americans that is scientifically and technologically illiterate" (National Commission on Excellence in Education, p. 12, 1983). Science education was affected by this document as it led to an overarching goal of promoting a scientifically literate society. The attempts to reform science education have been guided by the *Benchmarks for Science Literacy* [American Association for the Advancement of Science (AAAS), 1993] and the *National Science Education Standards* [NRC, 1996] (Lederman, 1999).

The recommendation of teaching the concept of scientific literacy is a result of combining the understanding of the nature of science (NOS) and inquiry. This concept of teaching scientific literacy was validated by the work of Showalter and by a National Science Teachers Association (NSTA) position statement on science-technology-society NSTA in 1982 (Lederman, Antink, & Bartos, p. 285, 2012). As a result, the prominent theme in the middle school science classroom today has been to teach the NOS (Bell, 2009). However, teaching and understanding he NOS has proven challenging, as there is not always a consensus among science educators and the scientific community about what exactly is meant by NOS (Lederman, 1999), and the NOS is a very broad term that has no specific definitive meaning, which further complicates things (Lederman, Antink, & Bartos, 2012). Despite the definitional challenges, the general consensus as to the meaning of the NOS is that it is referencing the central principles and ideas such as science is a way of knowing, is tentative, is based upon evidence, etc. (Lederman, Antink, and Bartos, 2012).

Having students understand the NOS is deemed a critical aspect of science education because it is thought to be a feature of scientific literacy (Bell, 2009). Indeed, if students have a thorough understanding of the NOS, they will be able to pass that knowledge on in the real world when they are presented with scientific claims and data (Lederman, 1999). While this theme of understanding the NOS is strongly emphasized and there has been repeated interest in teaching students about the NOS, little has been done to ensure that schools are following through with teaching the NOS as a way of attaining this “instructional goal” (p. 917, 1999).

For a variety of reasons, teachers are underprepared to teach students in a meaningful way and are hesitant to teach the NOS (Bell, 2009). To help alleviate this inconsistency of teaching the NOS, several different methods have been studied to see what is the most effective method to help students better understand the NOS. The incorporation of scientific literacy is one method that can be used to help with understanding the NOS (Bell, 2009). Scientific literacy studies and breaks science into three domains: a body of knowledge, a set of methods and processes, and way of knowing (Bell, 2009). Scientific inquiry is another method that can be used to help teach and understand the NOS. Too often though, scientific inquiry is thought to be just about exploring and experimenting, but it should also include argument and explanation (Sampson & Grooms, 2010).

Even with the availability of these different described methods above, science education continues to be taught in a traditional way in many schools and it lacks the relevance students need to have for an authentic science experience (Bell, 2009). While there are times when lecture and memorization are appropriate, learning is more meaningful to students when they can engage in activities that allow them to make connections to the real world and reflect on their experiences (Spector, Burkett, & Leard, 2007). So, while it is understood that science education should teach students about the NOS, there needs to be more effort put towards changing a teachers' classroom methods to reflect this reform (Lederman, 1999). Because of teachers' classroom methods reflecting a more traditional approach, students and teachers alike do not have a full grasp on understanding the NOS (Schwartz, Lederman, & Crawford, 2004). Therefore, the aim of science education reform of promoting a scientifically literate society is not being met.

Statement of the Problem of Practice

The suburban public middle school (grades six through eight) where the research was conducted serves a high population of students from the middle to upper levels of the socioeconomic status. Most student come from stable, two-parent households, and have parents that have a college education or higher. High student achievement is expected of the students. The teacher-researcher observed that the students can pass the state tests and common content-based summative grade level assessments because they can memorize and apply facts that they learn. So, on paper they appear to be doing well and understand science and seem to have an understanding of the content, but in reality, they struggle with thinking “scientifically”. Scientific thinking is when there is uncertainty surrounding an idea and that idea is not believed unless it is supported by evidence or proof (Enderle, Grooms and Sampson, 2013).

The students in the teacher-researcher’s class are great at asking scientific questions, but then they have problems with the practices of science. For example, the teacher-researcher has observed that when students are assigned a project-based activity, they excel at the planning stages of finding guiding questions, but they have little follow through in answering these questions. They also were able to make a claim but are unable to thoroughly support their claim with evidence and reasoning. Finally, students struggled with retaining content when it is taught in a student-centered approach such as a project-based activity and would prefer a more teacher-centered approach to learning science. Specifically, they struggled with arguing with evidence which is part of scientific proficiency and it is an essential skill for students to acquire (Enderle, Grooms, & Sampson, 2013). This critical thinking skill is a difficult, yet necessary part of learning about the NOS.

Argument-driven inquiry (ADI) can help improve the students’ understanding of the NOS by improving their science process skills, specifically in arguing with evidence. Enderle, Grooms, and Sampson (2013) have noticed the need for science classrooms to “shift from traditional, prescriptive activities to those that afford students the opportunity to engage in the practices of science such as argumentation” (p. 1). One strategy to make this shift away from traditional teaching and allowing them to use argumentation with evidence is the ADI instructional model (Enderle, Grooms, and Sampson, 2013). This model has seven different stages that focus on developing students' scientific proficiency skills. Scientific proficiency is the skills and knowledge a student needs to understand to be able to "function effectively in an increasingly complex, information-driven society" (Enderle, Grooms, and Sampson,2013, p. 1).

Lederman (1999) noted that an understanding of the NOS is linked to scientific literacy. Like scientific proficiency, scientific literacy allows students to understand, recognize, appreciate, and use science in their lives (Bell, 2009). Sampson and Grooms (2010) have also conducted research about teachers needing to give students opportunities to focus on "*how* we know science, and not just on *what* we know about the world" (p. 32). By the end of this study, therefore, it is hypothesized that using ADI helps to increase scientific proficiency skills, specifically developing evidence-based arguments, which are related to the NOS and scientific literacy.

Research Question

What impact will argument driven inquiry (ADI) have on the development of evidence-based arguments of eight eighth-grade general science students at a public middle school in the Southeast?

Purpose of the Study

The purpose of this study is to examine the impact of argument driven inquiry (ADI) on development evidence-based arguments for eight eighth-grade students enrolled in a regular general science class at a public middle school in the Southeast.

Methodology

This study was conducted for six weeks during the 2018-2019 third quarter at a public middle school in the southeast. Enrollment in the middle school is approximately

850 students grades six through eight. The teacher researcher was an insider as a participant and observer for the research since the study was conducted within her classroom and the participants were her students. The participants were eight eighth-grade students purposefully chosen from one eighth-grade general science classroom with a class size of 24 students. While all students participated in the treatment, data was collected on the eight students chosen to participate in the study. This enabled the researcher to stay within a locus of control used for research purposes (Metler, 2014). Students were purposely selected based upon results of an evidence-based pretest and a science questionnaire Likert attitudinal survey used at the beginning of the study.

A mixed-methods approach was used. At the beginning of the study, students were formally interviewed using open-ended questions about science and generating an evidence-based argument. The same questions were given to all participants. A content-based pre-test and post-test made with selection-type items was administered, and participants were given an attitudinal Likert scale about science. Over the course of the research period, students participated in two ADI activities. These were used as formative assessments and reviewed for content knowledge and the ability to generate an argument with evidence. These ADI activities were intended to help students understand the content, look at empirical data or theories, and show them what is considered scientific knowledge (Sampson & Grooms, 2010).

Observation field notes were taken two times a week during the ADI activities, and artifacts were collected on a regular basis. At the end of the study, students were formally interviewed again with open-ended questions about science and generating an evidence-based argument. A content-based post-test made with selection-type items and the attitudinal Likert scale was re-administered. Data collected was used to determine the extent to which ADI helped to improve a student's ability to generate an evidence-based argument.

Significance of the Study

What is deemed as necessary science is dictated by culture, and culture is what determines how we interpret and value data. Science and culture are directly correlated. Culture dictates what science is considered important and should be studied. Students need to learn how to apply their scientific knowledge to their daily lives regardless of their future career choice. Critical thinking skills and the ability to argue with evidence are skills that are applicable across a variety of fields. By widening and deepening their understanding of the NOS, students should be able to apply those skills to real-world situations.

If the aim of science education reform is to have a scientifically literate society, the hope of this study is to work toward that end. Students are strong in their content knowledge, but that is just one piece of being scientifically literate. By improving the students' understanding of the NOS, they will be able to use these skills in their daily lives and future careers.

Limitations of the Study

Limitations for this study include a small number of participants (n=8) and the six-week length of the research period. It is also limited to one classroom in a suburban middle school. Moreover, because of the small sample size and short time frame of the study, generalizations cannot be made, although that is the nature of action research.

Dissertation Overview

Chapter One of the dissertation included background information that showed the reasoning behind the study and the research question. Chapter Two offers a review relevant literature on social constructivist theories that ADI is grounded in, the NOS, scientific proficiency, and different methods for teaching middle school science. Chapter Three provides an in-depth summary of the methodology of the research. Chapter Four explains the findings and explanations of the action phase. Chapter Five includes the suggestions of the study along with recommendations for further research and an action plan.

Positionality

As a science teacher who has always had interest in the sciences, this study is important to me. Our global community is changing so fast with all the technological advancements that are happening. These advancements not only affect personal life but also society as a whole. Students need to be scientifically literate in order to make sense of all these advancements. They need to have a grasp on critical thinking so they can determine what is "good science" and pseudo-science in the media.   I also believe that students should be engaged in their search for academic truths and in the social issues of today. Students should be able to explore the world around them and review history to help find these truths and answers to our social issues. All children should learn how to maintain the desire to learn throughout life and how to apply that knowledge to help them become global citizens.

From an early age, I was introduced to science and how it shaped the world around me. This led to a natural curiosity of why things happened. Because I learned the discourse of school and science from an early age, I always thought science should be learned and taught in a very specific way. However, science is not just a body of knowledge and facts, which is a common misconception that people have about science.

Science is much more than that and should be taught in a much broader fashion, teaching the nature of science (NOS). Yes, the facts and general knowledge are important but so is the process of science. Teaching these details, such as argumentation, allow students to interact with science on a deeper level than just memorizing facts and formulas. This practical application and critical thinking of scientific principles is what drives me as a teacher. I want students to become scientifically literate and proficient so they can take those skills with them as they continue their educational experience and later in life as a productive citizen.

Definition of Terms

*Argument Driven Inquiry (ADI)***-** an instructional model that "give students an opportunity to learn how to use disciplinary core ideas, crosscutting concepts, and science and engineering practices to figure out how things work or why things happen" (Sampson, Murphy, Lipscomb, & Hutner, 2018, p. 3)

Argumentation – arguing with evidence

Evidence-Based Argument – when you use evidence for an argument; using claim, evidence and reasoning to argue

Nature of science (NOS) – no definitive definition exits but it is commonly referred to as the "nature of scientific knowledge". Refers to the central principles and ideas such as science is a way of knowing, science is tentative, science is based upon evidence, etc. (Lederman, Antink, and Bartos, 2012)

Scientific inquiry – “methods and activities that lead to the development of scientific knowledge” (Schwartz, Lederman, and Crawford, 2004, p. 612)

Scientific literacy – understanding science in the media, valuing and identifying science contributions, and using science to help with everyday decisions including socio-science issues (Bell, 2009)

Scientific proficiency – the knowledge and skills needed to perform in an information-driven society (Enderle, Grooms, and Sampson, 2013)

CHAPTER TWO

REVIEW OF LITERATURE

While the national goal for science education for over 100 years has been to teach the nature of science (NOS), major changes did not become noticeable until after the Soviet Union launched Sputnik in 1957. The launching of this Soviet satellite caused many questions to be raised as to why the United States was technologically behind the Soviet Union, and these questions led to adjustments in mathematical and science education (Demircioglu & Ucar, 2015). Specifically, scientific inquiry and laboratory training in primary through higher education became the main focus of science education (Anderson, 2007). Even though we are past the Sputnik era, there is still a major focus on science education teaching NOS as inquiry, and the argumentation aspect of inquiry can be considered a highly important part of scientific inquiry (Sampson, Grooms, & Walker, 2011). This is because argumentation plays an important role in the creation of scientific explanations and the creation of theories (Demircioglu & Ucar, 2015).

The previous chapter discussed a brief historical perspective of science education reform and how this theme of understanding the NOS is strongly emphasized. This chapter will include the theoretical frame for science education reform and review of existing literature about the NOS. The first section will describe the framework that helped develop this study. The second section will present a review of literature that supports scientific literacy, how to teach NOS, teacher education to promote NOS and its impact on scientific proficiency, and argumentation in science.

Theoretical Frame

Science education reform is based in progressivism curriculum theory. The National Science Education Standards stress the importance of students being involved in learning science through inquiry and scientific practices (Lotter, Smiley, Thompson & Dickenson, 2016). Engagement in inquiry and scientific practices allows students to actively generate their own understanding of science, as reasoning and thinking skills are intertwined with scientific knowledge. Progressivism was founded on the idea that children learn best when they are actively experiencing learning and an emphasis is placed on the child's interests and needs (Olivia & Gordon, 2013).

John Dewey developed a model for reflective inquiry which uses his ideas about the relationship between experience and education (as cited in Na & Song, 2014). He felt that science education should promote reflective thinking and problem solving among learners (Na & Song, 2014). The end result of progressivism is not just factual knowledge but a continuation of learning throughout a persons' entire life.

Constructivism

Constructivists view the teacher as the "facilitator of learning" (Olivia & Gordon, 2013, p. 136) and where individuals and groups interact with the environment and gain meaning from it (Wong, Firestone, Ronduen, & Bang, 2016). Having the teacher viewed as a mentor and having students actively engaged in their learning is similar to progressivism. Constructivism focuses on hands-on activities, activity-based learning, and students' development of their own structure of thought.

NOS should be taught in a manner where students are engaged in the practice of science (Capps & Crawford, 2013). The theoretical perspectives of Bandura's social cognitive theory of self-efficacy and Vygotsky's constructivist theory are also relevant. Project Based Learning (PBL) and Argument Driven Inquiry (ADI) model are two interventions that are rooted in social constructivists theories (Fallik, Eylon, & Rosenfeld, 2008 and Sampson, Grooms, & Walker, 2011).

Bandura's social cognitive theory. Bandura's social cognitive theory is based on the idea that individuals influence their own development and can make things happen through their own actions (Bandura, 1986). Self-efficacy is grounded on two dimensions of efficacy of beliefs: personal self-efficacy and outcome expectancy. The self-efficacy beliefs related to classroom practices are some of the most important factors influencing teacher practices, and efficacy beliefs can be task and content specific (Lotter, Smiley, Thompson, & Dickenson, 2016). If a teachers believe in themselves, then their teaching practices improve and this in turn improves the students' self-efficacy on the content.

This can be seen in a study conducted by McConnell, Parker, and Eberhardt (2013). The purpose of this study was to describe a strategy that was tested for assessing content knowledge of teachers. Research has shown that since many elementary and middle school teachers have not had extensive courses in science, professional development programs to strengthen content knowledge is useful. Content knowledge alone though is not enough to be an effective teacher, but a lack of content knowledge does affect teachers' ability to improve their practice. In this case, the relationship between personal self-efficacy and outcome expectancy can be seen. If a teacher is not confidant in their content knowledge, then their effectiveness as a teacher may not improve, and if a teacher has self-confidence, that can be transferred to students in believing in their ability to learn science. Science therefore should be taught as inquiry, and teaching about NOS requires a specific skill set of knowledge and beliefs that develop over time (Capps & Crawford, 2013).

Vygotsky's constructivist theory. Vygotsky's constructivist theory of social discourse is the theoretical foundation for inquiry teaching, which is a major aim of science education. Since students need to interact with their environment, Vygotsky (1978) suggested that discourse could encourage engagement as language is not always impulsive in students but can be deliberate and help them own their thinking and behavior. His theory has three major themes: social interaction, the more knowledgeable other (MKO), and zone of proximal development (ZPD) (Crawford, 1996). MKO is anyone or anything that has more knowledge or a better understanding of the material. ZPD is the interval between a student's ability to do a task with others and doing the task independently, and this is where learning occurs (Crawford, 1996).

When looking at these themes, argument driven inquiry (ADI) is based upon ZPD. Vygotsky's theory and ADI support the idea that students should have a more active role in their learning, and the teacher's role should be more of a collaborator so learning becomes more of a reciprocal experience for teacher and student. Teachers should model and provide support in the early stages of ADI. As the student becomes more comfortable with the practice, then the ZPD changes and the teacher can truly be more of a facilitator; the student learns from his or her environment and gains meaning, which is at the heart of constructivism.

In summary, the ADI model is rooted in social constructivist theories. Learning practices of science such as scientific argumentation and content use both personal and social processes (Sampson, Grooms, & Walker, 2011). When looking at using the constructivist theory for teaching science in this manner, there are two potential outcomes. First, students engage in authentic scientific practices that use reasoning and discursive practices of scientists to learn from their experiences. Second, students must develop an understanding about what makes some practices in science more useful and thus different from other ways of knowing (Sampson, Grooms, & Walker, 2011). Science education reform has been shifting science education from rote memorization and recall to inquiry and questions which causes the students to become active recipients. Teachers are becoming facilitators, and critical thinking practices have become a tool for promoting scientific literacy (Gunn, & Pomahac, 2008).

What is Science Proficiency

Science proficiency signifies the skills and knowledge that people should have in order to be able to function effectively in the technology and information-driven society that we are becoming (Enderle, Grooms, & Sampson, 2013). The skills and knowledge that are needed to become scientifically proficient include using and understanding scientific explanations about the natural world, understanding the characteristics of scientific knowledge and how it is developed, being able to make and assess scientific arguments and explanations, and effectively participating in the practices and conversations of the scientific community (Enderle, Grooms, & Sampson, 2013).

As science education changes from rote memorization to inquiry and questioning, two research themes stand out: the four strands of scientific proficiencies and the phases of inquiry (LeBlanc, Cavlazoglu, Scogin, & Stuessy, 2016; Minogue, Madden, Bedward, Wiebe, & Carter, 2010). Both of these help students understand authentic science practices because knowledge and practice are essential to scientific proficiency. The four strands of scientific proficiencies consist of "(1) understanding scientific explanations, (2) generating scientific evidence, (3) reflecting on scientific knowledge, and (4) participating productively in science" (LeBlanc, Cavlazoglu, Scogin, & Stuessy, 2016, p. 172).

The phases of inquiry are immersion, research question, experimental design, observation, and conclusion (LeBlanc, Cavlazoglu, Scogin, & Stuessy, 2016; Minogue, Madden, Bedward, Wiebe, & Carter, 2010). Research has shown that when the four strands are included in the classroom, scientific proficiency is developed (e.g., LeBlanc, Cavlazoglu, Scogin, & Stuessy, 2016; Minogue, Madden, Bedward, Wiebe, & Carter, 2010).

In a study by LeBlanc, Cavlazoglu, Scogin, and Stuessy (2016), research was conducted to illustrate how a teacher's discussion about different strands of scientific proficiencies changed during an inquiry cycle with students engaged in an inquiry-based project. The main question being studied was, "How does the teacher's discussion of each scientific proficiency change over the course of the inquiry cycle?" The research was descriptive in nature and attempted to analyze the intricacy of teacher talk in the classroom as it is related to the strands of scientific proficiency. An exploratory sequential mixed methods design was used for this study. One teacher was the participant of this study. Twenty video-recorded sequential inquiry lessons used over a six-week time period were used as data.

The study was broken into two parts. During the first phase, the teacher's comments about inquiry were transcribed and each class/lab's phase of inquiry was identified. This was done to uncover and identify which inquiry phase was being used throughout the course of the full inquiry sequence. In the second phase, coding was used on the teacher's transcribed inquiry comments by using the Science Proficiency Rubric. These codes were used to calculate the use of each scientific proficiency during the inquiry cycle. The study showed that the teacher's reference to scientific proficiency during the inquiry cycle followed a repetitive track. All four proficiencies were referenced during the inquiry cycle but some proficiencies were used more than others in certain parts of the cycle. The findings support previous research that state scientific proficiency strands and the inquiry phases are linked and connected (LeBlanc, Cavlazoglu, Scogin, & Stuessy, 2016).

Having a wide variety of learning experiences in the classroom helps students meet the goals of science proficiency (Minogue, Madden, Bedward, Wiebe, & Carter, 2010). There is a need for basic understanding of some science concepts in order to have background knowledge and the ability to interpret data. With the amount of scientific news in the media, students need to be able to make personal decisions based upon what they hear and see. The ability to teach our students to apply their understanding of NOS is imperative to their scientific literacy**.**

What is Scientific Literacy

The phrase scientific literacy has been used in science reform for over 50 years and is used in conjunction with understanding NOS and scientific inquiry (Lederman, Antink, & Bartos, 2012). Prior to discussion of NOS and to help understand NOS, one must look at scientific literacy. Scientific literacy can be considered being able to understand science that is presented in the media, acknowledging and valuing the influence of science, and using science with every day and societal issues (Bell, 2009).

The terms science literacy and scientific literacy have been interchanged at times, but there are differences between them. Science literacy was used by the American Association for the Advancement of Science in 1993 and has a focus on "the knowledge, processes, and products of science" (Lederman, Antink, & Bartos, 2012, p. 286). Scientific literacy includes this knowledge of science but applies the knowledge to decisions about personal and societal issues that may or not be scientific in nature (Lederman, Antink, & Bartos, 2012).

Scientific literacy studies and breaks science into three domains: a body of knowledge, a set of methods and processes, and way of knowing (Bell, 2009). The first domain of scientific literacy is that science is a body of knowledge. The second domain is the typical scientific methodologies that are used to generate knowledge. The third domain is the vaguest and is also known as NOS. Scientific knowledge has been considered the set of science facts, theories, laws, and concepts and can be considered the social and cultural values of science and the value and beliefs surrounding scientific knowledge (Cibik, 2016).

Allchin (2011) wrote the article, "*Evaluating Knowledge of the Nature of (Whole) Science*", and the purpose of this one piece was to propose an alternate model for assessing NOS knowledge to use in place of the Views of Nature of Science (VNOS) and similar methods. Due to the amount of scientific news that is presented in the media, students need to make personal decisions based upon what is presented by the media. There is a need for basic understanding of some science concepts in order to have the background knowledge and ability to interpret data that has been presented by the media. The ability for educators to assess, in a standardized way, how well they can analyze a students' ability and understanding of NOS is a major weakness. Based on current standardized testing measures, teachers are still teaching to the test of content and not an understanding of NOS (Allchin, 2011).

Allchin (2011) discussed a prototype that was developed from a series of questions a typical person may encounter in the news media. They asked for a well-informed analysis of the case that was not looking for content knowledge alone but rather how the student could show their understanding of the NOS about the topic. Therefore, content knowledge is not enough to answer this question. What students need to learn is what or whom they can trust for information (Allchin, 2011). In other words, they need to figure out how to find a credible source and explain why it is credible. The ability for people to determine the reliability of knowledge and use it for informed decisions is the core of scientific literacy.

One intervention that can be used to develop scientific literacy in students is the use of socio-scientific studies. In their article, "*Nature of Science, Scientific Inquiry, and Socio-Scientific Issues Arising From Genetics: A Pathway to Developing a Scientifically Literate Citizenry*", Lederman, Antink, and Bell (2012) assert how teachers can use socio-scientific studies to teach scientific knowledge and scientific literacy. Socio-scientific studies are controversial social issues that relate to science, and their article gave thorough descriptions of scientific inquiry and the nature of scientific knowledge. Both are considered an integral part of scientific literacy. Three examples were given in the article to show how genetics could be used to help with NOS and scientific inquiry and thus promote success at improving scientific literacy in students. The first example was based on genetically modified food, the second was genetic testing, and the third used stem cell research. All three of these topics are considered controversial and show how science impacts us on a societal level.

Another way to help incorporate scientific literacy into the classroom is through the use of disciplinary literacy. As students get older and enter middle and high school, explicit reading classes are often not offered, which are common in elementary school. Because of this, generalizable content area reading education is common across content areas (Shanahan & Shanahan, 2012). Disciplinary literacy "emphasizes the unique tools that the experts in a discipline use to engage in the work of that discipline" and "emphasizes the description of unique uses and implications of literacy use within the various disciplines" (Shanahan & Shanahan, 2012, p. 8). When compared to content area literacy, disciplinary literacy provides instruction on how to read a text as an insider (scientist, historian, etc.) would and give them an insider's perspective of the material and not just the tools with remembering the information. This approach is helpful with scientific literacy because it offers clear guidance to help students understand the how integral and specialized literacy is in science.

Therefore, the goal is to create informed students so they can make scientifically based decisions with personal and societal issues in mind. Teaching NOS and scientific inquiry can be accomplished using relevant socio-scientific issues and disciplinary literacy as they help develop scientific literacy by allowing for a deeper understanding and conceptualizations of content material.

What is Nature of Science

Irzik and Nola (2011) stated that there is an overall agreement in the science education literature that students should learn content and the NOS. But determining what exactly is meant by NOS is the issue. NOS is given the general characterization as the epistemology of science and sociology of science (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002), yet many researchers have noted that there is no definitive definition for NOS (e.g. Wong, Firestone, Ronduen, & Bang, 2016; Cibik, 2016; Lederman, Lederman, & Antink, 2013; Bell, 1999; Herman, Clough, & Olson, 2013). Scientific knowledge can be thought about as being fluid, empirically based, using human inferences, socially embedded, and understanding the difference between observations and inferences and scientific laws and theories (Lederman, Antink, & Bartos, 2012). While the characterizations of NOS are general, it can be agreed that the conceptions of NOS are uncertain and dynamic (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). Often, NOS is considered mutual with science processes, but they are not communal. Science processes are the activities related to data collection, interpretation, and conclusion while NOS is focused on the "values and epistemological assumptions underlying these activities" (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002, p.499).

With NOS having such a general meaning, two views have been emerged about it: the consensus view and the family resemblance approach. Norman Lederman and his collaborators were proponents of the consensus view (as cited in Irzik & Nola, 2011). That view states that students should only learn widely-accepted characteristics, which happen to be the least controversial parts of NOS. The consensus view seems to show too narrow of a picture of what science is, and methodology seems to be written off; NOS seems to be fixed and timeless, and there seems to be a lack of systemic unity (Irzik & Nola, 2011).

There has been criticism with the consensus view, however, as it focuses on scientific knowledge and misses the nature of scientific inquiry (Berkovitz, 2017). Therefore, Irzik and Nola (2011) came up with the family resemblance approach to offset these limitations of the consensus view of NOS. This approach is not new and was developed by Wittgenstein (1958) (as cited in Irzik &Nola, 2011, p. 593). What the authors have done is to develop this approach so that NOS can be presented in a deeper way and give an alternative to the consensus view. This view will point out that there are many common characteristics of all sciences, but these characteristics do not define science as a whole. Observing and experimenting are very common, but not all sciences are experimental. So, if one thinks of science as just observing and experimenting, one is not looking at all types of science disciplines. By looking at these similarities and differences between the science disciplines, NOS can be organized by activities, aims and values, methodologies, and methodological rules and products. The family resemblance approach to NOS can now be seen as more comprehensive when compared with the consensus view, as it shows the dynamics and open-ended NOS (Irzik &Nola, 2011).

Teaching the nature of science. Nature of science (NOS) should be considered the basis for science education today (Vazquez-Alonso, Garcia-Carmona, Manassero-Mas, & Bennassar-Roig, 2013). Characteristics of NOS include "understanding the importance of observations and inferences, as well as the tentativeness, subjectivity, and cultural aspects of science associated with the development of scientific knowledge" (Capps &Crawford, 2013, p. 501). In order for teachers to teach NOS, they need to have an understanding of NOS and be able to communicate this knowledge to their students through suitable classroom practices. This follows the constructivist viewpoint in that if teachers teach and are facilitators of NOS, then scientific literate students will be able to learn science and NOS through their own experiences (Cibik, 2016). Teaching NOS increases students interest and helps develop awareness of how science influences society (Bell, 1999).

Self-efficacy has been noted as an important factor that influences how teachers implement a new strategy, and self-efficacy can be improved in teachers when they partake in professional development (PD) that gives explicit NOS instruction (Wong, Firestone, Ronduen, & Bang, 2016). Providing teachers with authentic experiences and engaging them in PD that demonstrates a given methodology have been shown to have a significant impact on their understanding of the instructional practices (Lotter, Smiley, Thompson, & Dickenson, 2016). Research has also shown that there is a need for teachers to engage in continued NOS PD to continue to develop and maintain the conceptions of NOS (Wong, Firestone, Ronduen, & Bang, 2016).

One trend that has been seen with teacher education is that while new pedagogies are given to help with teaching NOS, the new methods are not being used in the classroom (Fallik, Eylon, & Rosenfeld, 2008). One reason for this lack of implementation is that there was little feeling of ownership with the new teaching methodologies. In order for teachers to feel the desire to enact the new constructivist methods, their personal learning preferences, the ability to customize what they are teaching, and having support were seen to be instrumental in teacher adoption of the new methods (Fallik, Eylon, & Rosenfeld, 2008).

Vazquez-Alonso, Garcia-Carmona, Manassero-Mas, & Bennassar-Roig (2013) conducted a study to describe the results of an evaluation of teachers' understandings about the NOS. A large sample of Spanish pre-and in-service science teachers were compared and used to diagnose their strengths and weaknesses. It focused on teachers in Spain and was conducted to identify Spanish science teacher's ideas about NOS to verify if specific deficiencies could prevent them from teaching the new NOS curriculum. It was also studied to determine if the lack of institutionally-promoted PD had a difference on the ability of an experienced teacher to be able to teach the new NOS content effectively or if specific NOS training is needed. This showed that differences between years of experience teaching science could help teachers acquire the teachers' content knowledge on NOS (Vazquez-Alonso, Garcia-Carmona, Manassero-Mas, & Bennassar-Roig, 2013). Therefore, this variable was considered to have value in a study to test experience as having an influence on teachers' NOS content knowledge (Vazquez-Alonso, Garcia-Carmona, Manassero-Mas, & Bennassar-Roig, 2013).

For this study, 774 science teachers from different universities and primary and secondary school teachers from around Spain participated in this study (Vazquez-Alonso, Garcia-Carmona, Manassero-Mas, & Bennassar-Roig, 2013). Of these 774 teachers, 494 were pre-service teachers, and 280 were in-service science teachers of various science subjects. The study used voluntary teacher participants, but they were not randomly selected. The study used quantitative methodology to find answers to questions about the general strengths and weakness of teachers' conceptions about NOS. The Spanish "Opinions about Science, Technology and Society Questionnaire" was used for data collection.

The results showed the weaknesses and strengths of the teachers' NOS conceptions. They somewhat duplicated previous findings in NOS literature but there were also features found that were determined to be different from previous research. Similarities to prior NOS finding in the literature included that Spanish science teachers have similar misconceptions about science such as "objectivist, realist, empirical, etc." (Vazquez-Alonso, Garcia-Carmona, Manassero-Mas, & Bennassar-Roig, 2013, p. 800). It also showed that the teachers thought most scientists follow the steps of the scientific method and view the scientific method as a guarantee to "valid, clear, logical, and accurate results" (Vazquez-Alonso, Garcia-Carmona, Manassero-Mas, & Bennassar-Roig, 2013, p.800). The teachers also had a realist viewpoint instead of instrumentalism about the statement that scientists discover scientific knowledge based upon experimental facts. This means that with a realist viewpoint of science, theories describe and explain what happens in the world accurately, even if it is not observable; whereas with an instrumentalist viewpoint, science is a tool that is used to explain and predict phenomena in the world.

Therefore, since most teachers had a realist viewpoint, scientific knowledge is based upon the truths found with experimental facts. Overall, the teachers' thinking had more positive ideas than negative ones about their understanding of NOS, which is opposite of the results from prior research on teachers' understanding of NOS (for example, Lederman, Lederman, & Antink, 2013). The findings determined that the science teachers did not have overall mastery of NOS issues even though they did show informed ideas about NOS (Vazquez-Alonso, Garcia-Carmona, Manassero-Mas, & Bennassar-Roig, 2013).

While much stress is emphasized on students learning NOS and there is a pull away from traditional teaching that involves rote memorization, it is noteworthy that it is essential for science teachers to have a thorough understanding of the content they are teaching. Having content knowledge is not indicative of effective teaching but it does influence a teacher's ability to improve their practice (McConnell, Parker, & Eberhardt, (2013). Content knowledge is critical for effective science teaching because as students engage in NOS and inquiry, teachers need to be able to identify and address misconceptions in students' written and verbal statements, construct tasks for inquiry that lead to a deeper understanding of concepts, and explain and help connect ideas (McConnell, Parker, & Eberhardt, 2013). Again though, content knowledge is not enough to be an effective science teacher for conceptual understanding. What it does allow though, is for a teacher to improve their practice and be able to properly implement strategies for teaching NOS. Several interventions can be used to help teach NOS, such as problem-based learning (PBL) and scientific inquiry.

Project-based learning. Project-based learning (PBL) is a constructivist strategy that uses inquiry skills to develop research or design a product (Fallick, Eylon, & Rosenfeld, 2008). John Dewey was an advocate of projects to learn by doing, as they are based on the students' interests (Fallick, Eylon, & Rosenfeld, 2008). PBL has a long history, and today there are different variations of PBL; but the basic criteria include the following: centrality, driving question, constructive investigations, autonomy, and realism (Fallick, Eylon, & Rosenfeld, 2008). PBL is one approach to teaching NOS in which students obtain information by themselves using scientific process skills about an authentic question, problem, or challenge and develop a solution that is communicated (Cibik, 2016). Herro and Quigley (2017) noted that PBL students perform better on content knowledge assessments as compared to students taught with traditional teaching.

Fallik, Eylon, and Rosenfeld (2008), studied the usefulness of one long-term effort to provide support for successfully implementing PBL strategies during continuous professional development (CPD) about PBL in Science and Technology. Of the two studies they conducted, one was for the framework for new teachers and the other was for teachers with five years or more experience. The first study was conducted using novice teachers. Three groups of middle school science and technology teachers (N=58) participated in the first support framework. The teachers attending the workshop participated in the process of design and technological development instead of the process of scientific research. The process of design and technological development each group focused on varied.

Group one had a central subject of transport systems, group two had a central subject of materials, and group three had a central subject of senses and sensors. There were two parts of data collection: closed-ended response and open-ended response in the form of questionnaires. For the second study, seven expert teachers from the three middle schools were chosen as participants. Instead of participating in a workshop, these teachers participated in project-based learning as Science and Technology (PBLSAT) learners. PBLST is a modified PBL approach that was developed for middle school teachers in Israel (Fallik, Eylon, & Rosenfeld, 2008). In-depth interviews with open-ended questions were conducted for data collection. Teachers in the first study reported that the workshop held great value in improving the PBLSAT skills. They felt strongly about the importance of PBLSAT but were worried about the difficulties in the future of using PBLSAT. These difficulties were made obvious during the workshop, but the teachers felt they had enough support to overcome them. The teachers in the second study became a resource for the novice teachers. Both groups of teachers felt that they had developed personally and professionally (Fallik, Eylon, & Rosenfeld, 2008).

Cibik (2016) conducted a study to compare the change of pre-service science teachers' views about NOS through PBL and Nature of Science training and Conventional Method. The study also hoped to answer the following questions: was there any significant difference in pre- and post-test scores between the experimental and control group, what was the distribution of open-ended questions from the pre- and post-test of Student Understanding of Science and Scientific Inquiry (SUSSI) questionnaire from the experimental and control group, and finally, how did the experimental group feel about the method after the treatment? The study used both qualitative and quantitative methods and utilized a non-equivalent control group design out of a quasi-experimental design.

Two randomly chosen groups of third year undergraduate students were the participants in this study. The experimental group had N=41 and the control group was N=46. The experimental group received training through PBL and the control group through conventional methods (CM). SUSSI questionnaires were administered to both groups as a pre- and post-test, and both groups were evaluated qualitatively and quantitatively. Findings showed that pre-test scores from both the experimental and control group had comparable opinions of test items that were coded as not classifiable and naïve views. The experimental group showed positive growth of NOS knowledge with the codes of transitional views and informed views while the control group stayed in the not classifiable and naïve views. Post-test data showed that the experimental group had improved their knowledge and had positively changed their views about NOS after their PBL training. Therefore, it can be concluded that PBL method is an effective method for changing views of teachers about NOS in a positive way (Cibik, 2016). If teachers become comfortable in using PBL through personal experience, then they are more comfortable engaging students with this method, which has been proven to increase NOS understanding.

Scientific inquiry. One of the major aims of science education in the United States is for all students to develop an understanding of scientific inquiry and the abilities needed to participate in an inquiry by the time they graduate high school (National Research Council, 1996). Scientific inquiry is related to scientific processes but differs as it includes these traditional scientific practices (e.g., observing, inferring, classifying) and combines these processes "with scientific knowledge, scientific reasoning, and critical thinking to develop scientific knowledge" (Lederman, Lederman, & Antink, 2013, p.142). While the focus has been placed on student engagement in inquiry and scientific practices, there is still a lack of student engagement in inquiry (Lotter, Smiley, Thompson, & Dickenson, 2016).

The theoretical framework for inquiry-based teaching can be seen in Dewey's "educative experience" (1938), Duckworth's "wonderful ideas" (1987), and Vygotsky's "social discourse" (1978) (McHenry & Borger, 2013). These individuals can be considered interactionists as they believe that the main focus of education should not be the learner and the environment but rather the interaction between the learner and the environment. However, many educators still balk at using inquiry for teaching science.

Elementary teachers most often stated that they did not teach science using inquiry because they had not experienced authentic scientific inquiry and they themselves were not successful at science in school (Spector, Burkett, & Leard, 2007). Teaching science using inquiry is not the only way to teach science, but it is a focus of science education reform due to how it helps students develop their critical thinking skills and their understanding of science (Capps & Crawford, 2013). Inquiry is based on students generating their own questions and allows students to engage in authentic scientific practices (LeBlanc, Cavlazoglu, Scogin, & Stuessy, 2016). Inquiry also follows the constructivist's viewpoint that students will learn science best when they are doing science (Lederman, Lederman, & Antink, 2013).

Spector, Burkett, and Leard (2007) conducted a qualitative emergent-design study to see if using an experimental learning strategy could lessen pre-service teachers' resistance of using inquiry in the elementary science classroom. Participants in the study used themselves as a learning laboratory so that they could have meaningful experiences with using inquiry-based science instruction. Data sources included participant observations, electronic artifacts, and interviews. Twenty-one undergraduate and forty-six graduate students in a science methods course participated in the class that was required for their degree, and results were used for the findings of this study. The course used an experimental approach to allow participants to learn teaching methods for national and state standards and was meant to shift from traditional teaching to inquiry-based teaching. The study found that pre-service teachers need to be given multiple methodologies such as reflection, group debriefing, and self-evaluation to show the importance of teaching science through inquiry. Allowing pre-service teachers the opportunity to experience inquiry themselves as learners enabled them to understand the learner's benefits of using inquiry (Spector, Burkett, and Leard, 2007).

Lotter, Smiley, Thompson, & Dickenson (2016) conducted a study to observe how a PD model influenced science teachers' understanding and practices about inquiry-based instruction. The PD model used was intended to involve teachers in inquiry content instruction, practice teaching students, and to collaborate about reflections on inquiry teaching. This study used a mixed-methods approach, specifically a parallel mixed analysis, to gather information about teachers' perceived effectiveness for Teaching Science as Inquiry (TSI) and their actual inquiry teaching methods. Middle school teachers from the Southeastern United States were involved in a one-year inquiry-based PD program. A total of 25 teachers completed all research requirements. Qualitative and quantitative research strategies were used. Teachers' responses to open-ended questionnaires that were given before and after the two-week institute and at the end of the year were collected and coded. Final written reflections about various PD components were also collected.

Results showed a statistically significant increase in their self-efficacy for teaching inquiry in four out of five essential features (instructional, discourse, assessment, and total inquiry level). After the PD program, an increase in teachers' quality of inquiry teaching was also noted (Lotter, Smiley, Thompson, & Dickenson, 2016). Overall, this study showed a link between a teacher's efficacy and their inquiry teaching skills. If teachers with low self-efficacy are given opportunities for PD that allow them to practice inquiry, their quality of teaching inquiry will improve to that of a teacher who has high self-efficacy about inquiry teaching prior to any PD on inquiry (Lotter, Smiley, Thompson, & Dickenson, 2016).

Argumentation in science education. The *National Science Education Standards* state that science should be taught using inquiry as a process of "exploration and experiment" and that there is a need for opportunities to engage in scientific argumentation (National Research Council [NRC], 1996, p. 113). Argumentation is an important part of inquiry because it allows learners to develop and refine scientific knowledge (Grooms, Enderle, & Sampson, 2015) but is often not used (Sampson, Grooms, & Walker, 2011). Empirical research has shown that students are not developing the knowledge or skills because they are not afforded an opportunity to engage in scientific argumentation or learn how scientific argumentation is different than other forms of argumentation (NRC, 1996). Scientific argumentation is one of the characteristics of science that makes it different from other types of knowledge (Grooms, Enderle, & Sampson, 2015).

In science, argumentation is not about having a winning or losing side; rather it is about using discussion or writing in which the relationship between ideas is found and can be supported with evidence. Activities used should change the focus from what we know about the world and how it works to how we know science (Sampson & Grooms, 2010). Most often, science classes are structured in a manner where "the emphasis is often on doing rather than on thinking and little time is set aside for discussion, argumentation, and negotiation of meanings" (Kim & Song, 2005, pp.211-212). When these integral parts of NOS are left out, students start viewing science in a different way. They miss the important aspect that science can change, they start thinking it is unproblematic, and lastly they lose the desire to look at scientific claims in a critical manner (Kim & Song, 2005).

Argumentation in science is an intervention for scientific inquiry, as a goal of scientific inquiry is the generation and justification of knowledge (Kim & Song, 2005). This is a wide goal, but research on students learning science through scientific inquiry has shown two main concentrations emerge: using data and scientific concepts to construct models or explanations and engagement in scientific discourse for proposing and arguing ideas (Berland & Reiser, 2009). Since the goal of science education is have students engage in scientific practices such as argumentation, teachers must be able to identify and show the features of the practice and how to create the explanations (Berland & Reiser, 2009). For example, if we are attempting to have students engage in knowledge construction, they need to be shown and understand how explanations are constructed and be shown the social context that makes it meaningful. In scientific communities, the explanation of the results of a study are questioned, evaluated, and revised, which means argumentation is used to develop these explanations (Berland & Reiser, 2009).

Teaching argumentation with appropriate activities can improve the students' conceptual understanding of science. One activity that helps promote argumentation is presenting students with tasks that require debate and discussion (Simon, Erduran, & Osborne, 2006). Students need to be able to work in groups and to listen and communicate their ideas in order for argumentation to occur. Oral discussion is important with argumentation, but writing during and after an activity also improves students' argumentation skills (Simon, Erduran, & Osborne, 2006).

Kim and Song (2005) conducted a study to examine the features of peer argumentation among students during scientific inquiry. They thought that it was necessary to examine the relationship between evidence and claims and allow students to defend their views since little research has been conducted about this. Having this ability allows students to learn the norms of language in the scientific community. Eight 8th-grade student volunteers and their teacher from a middle school in Seoul, Korea, participated in this study. Students were divided into three groups and completed open inquiry activities outside of the normal school year. The students would complete the experiment activity, write a group report for peer review, and finally, present oral argumentation in a critical discussion. Data used were audio and videotapes of discussions, copies of student reports, student questionnaires, and transcripts from student interviews. Results showed that the typical peer discussion went through four stages: focusing, exchanging, debating, and closing. Argumentation was noted to be a social activity as much as it was a cognitive one. The cognitive strategies used were questioning, elaboration, clarification, using an analogy, hypothesizing, and authorization. Social strategies used would either cause conflict or cooperation to control the stage of the discussion. The focusing stage seemed to be an important factor in having an effective critical discussion. Overall, students showed improvement with their method of experiment and interpretation during the argumentation process (Kim & Song 2005).

In a different study by Berland and Reiser (2009), the meaning of student participation in scientific inquiry practices was examined. The instructional goals of using evidence and basic science concepts to make sense of the specific content being studied, articulating these understandings, and persuading others of the explanations were identified for constructing and defending explanations. These goals where suggested to be used as the framework for understanding how students participate when constructing and defending explanations. It was also noted that the strengths and weaknesses of the students' ability to practice constructing and defending scientific explanations need to be in the context of a learning environment that is designed to help this practice (Berland & Reiser, 2009).

The learning environment that was chosen to facilitate this study was the Investigating and Questioning our World Through Science and Technology (IQWST) (Berland & Reiser, 2009). The IQWST method was not being tested for this study, as it was already proven to support students in constructing and defending scientific explanations. Instead, the IQWST was used as a context for examining the strengths and weaknesses students have when they are not supported and to test the usefulness of the three goals (sensemaking, articulating, and persuading) for identifying these strengths and weaknesses. Three classes were selected for diversity purposes (N=53) to complete two units using IQWST. The selected explanatory questions included in the data set was also used for variety. The different ways teachers emphasized different aspects gave a realistic view on how teachers support the practice of constructing and defending scientific explanations. This variety also increased the likelihood of students answering multiple ways. Daily videotapes, pre- and post-tests, pre- and post-interviews, with a subset of the students, and all written work was used for data analysis (Berland & Reiser, 2009).

This study showed two patterns: students that embedded their evidence and claims and those that explained them (Berland & Reiser, 2009). It was also noted that students accomplished the first two goals of sensemaking and articulating consistently but did not consistently use the third goal of persuading. It appeared that this could be due to a lack of social interactions in a traditional classroom setting. This agrees with the third instructional goal of constructing and defending scientific arguments being of a social nature in which an audience is persuaded with an argument. Traditional classrooms do not present a reason for students to persuade an argument because the teacher is thought of as the fact presenter with facts that students need to memorize (Berland & Reiser, 2009).

As science education continued down the path of constructivism, the focal point of a science classroom shifted from the teacher to students, and instructional models started to form that stressed knowledge construction and validation through inquiry. Two of these models, Science Writing Heuristic and Modeling Instruction, developed to allow students to have more opportunities to construct explanations and share them with small groups or whole class discussions (Sampson, Grooms, & Walker, 2011). These models were formed to create classroom communities that encouraged students learning from their environment, specifically learning to understand, scientific explanations, generate evidence, and reflect on scientific knowledge (Sampson, Grooms, & Walker, 2011).   It was believed that the use of these models would help with the major aims of science education in the United States: that all students develop an understanding of scientific inquiry and the abilities needed to participate in inquiry (NRC, 1996).

Science Writing Heuristic. Science Writing Heuristic (SWH) is an argument-based inquiry instructional model that incorporates language to help students learn scientific inquiry (Myeong-Kyeong Shin, & Jeonghee, 2012). Students often find it difficult to participate with argumentation in science because they have not learned the goals and processes of argumentation in the traditional classroom setting. SWH is designed so that students can use reasoning to change evidence into knowledge that is similar to scientists' reasoning and writing (Akkus, Gunel, & Hand, 2007). SWH has a teacher and student template, giving it two different components (Keys, Hand, & Prain, 1999). SWH continues with the constructivists' view that learning should be student-centered so that students can construct knowledge and meaning from their experiences.

Modeling Instruction. Modeling Instruction is an important part of science education in which students create interactive conceptual models. Modeling is one of the eight science and engineering science practices recommended by the NGSS (NGSS Lead States, 2013). It helps to promote science learning and may correct students' misconceptions about topics (Chang, 2008). There are two main stages of modeling instruction: model development and model deployment (Jackson, Dukerich, & Hestenes, 2008). The model development stage generally begins with the teacher leading and then breaks into small groups for discussions on potential plans. In the model deployment stage, students apply their model to new situations to deepen their understanding of the content (Jackson, Dukerich, & Hestenes, 2008). This intervention also is in line with the constructivist theory as students are learning and constructing knowledge from their experiences.

Argument-Driven Inquiry. The Argument-Driven Inquiry (ADI) instructional model is devised as a strategy to aid in the development of four key features of scientific proficiency: knowing scientific explanations, using scientific explanations, generating scientific explanations and arguments, and communicating in writing (Enderle, Grooms, & Sampson, 2013). It was created by Sampson, Grooms, and Walker (2011) to address the move from traditional laboratory practices to practices that allow students to have more opportunities to improve their understandings and skills in scientific argumentation. ADI is similar to other instructional models because the design is meant to change traditional laboratory instruction so students are able to learn how to develop methods of data collection, carry out investigations, write, and be reflective in their practices (Sampson, Grooms, & Walker, 2011).

The key difference between ADI and other instructional models is that it allows students to engage in other scientific practices such as argumentation and peer review. By combing these differences and similarities, Sampson, Grooms, and Walker (2011) believed that their model allowed students to "begin to develop the abilities needed to engage in scientific argumentation, understand how to craft written arguments, and learn important content as part of the process" (p. 219). As instruction moves away from traditional teaching to one that stresses knowledge construction and validation through inquiry, the ADI model adds to this focus by allowing students to participate in other scientific practices.

Sampson, Grooms, and Walker (2011) conducted an exploratory formative investigation to develop a new instructional model to influence how students participate in scientific argumentation and craft writing. This new model they created was called the Argument-Driven Inquiry model (ADI) and was intended to be used as a template used for designing authentic and educational laboratory activities. This study focused on both process and product to the different parts of this scientific practice to help avoid biases. The ADI model has seven steps and is defined by the scope and purpose. Each step is equally important so therefore, they are interrelated and work together with the other steps. Nineteen 10th grade students from a small private school chose to participate in the study. The students were randomly assigned to one of six groups and were then asked to complete a performance task prior to the first ADI lab investigation. Teacher help and support was not given, and the students' work was video recorded.

At the end of the 18-week ADI intervention, each group completed the same performance task in the same manner as the first performance task. The results imply that students were better engaged and produced better arguments after the intervention (Sampson, Grooms, & Walker, 2011). This gave implications that developing argumentation skills was more than just putting students together in groups to develop an evidence-based argument or explanation for a natural phenomenon. Rather, it showed that developing the abilities and knowledge to acquire skill in scientific argumentation was a social process as well as a conceptual and cognitive practice (Sampson, Grooms, & Walker, 2011).

Enderle, Grooms, and Sampson (2013) conducted a comparative case study that explored how laboratory instruction in a high school biology class affected the development or diminution of science proficiency over a given period of time. Four different assessments were administered at the beginning and end of the year. The assessments measured the students' knowledge and ability to use scientific explanations, ability for argumentative wring that was specific to science, ability to construct an investigation that leads to generation of an argument to respond to a research question, and their understanding of the change and nature of scientific information (Enderle, Grooms, and Sampson, 2013). Results were used to determine the rate of change of the students' performance. The objective of the study was not to measure mastery of content but rather how the instructional context was learned. The study was conducted at two different high schools. Two teachers from each school participated. The teacher from School A used ADI laboratories, and the teacher from School B used traditional laboratories. Results showed students in both contexts (ADI model and no ADI model) statistically gained content knowledge and improved upon their performance task scores. However, the students that participated in the ADI model increased in their scientific writing and understanding of the development and understanding of the nature of scientific knowledge. Overall, the use of the ADI model showed it can be useful to improve students' scientific proficiency.

Grooms, Enderle, & Sampson (2015) wrote an article to discuss scientific argumentation (which is part of the Next Generation Science Standards [NGSS]) using argument-driven inquiry. The NGSS (2013) addresses argumentation as only one of the eight essential practices in the NGSS and can be viewed as having a critical role in students learning contexts and understanding science concepts. Grooms, Enderle, & Sampson (2015) also discussed the importance of having a science classroom that is based on the constructs of science proficiency. Argument driven inquiry aligns with multiple parts of the NGSS and scientific proficiency framework, but it is only one strategy that has the potential to be useful in adopting the new science standards. Classrooms are going to need to realign with the NGSS, and argument driven inquiry is one way that teachers can help transition toward quality science teaching (Groom, Enderle, & Sampson, 2015).

Conclusion

The research reviewed in this chapter shows that the aims of science education reform in the United States have shifted from traditional teaching to improving the scientific proficiency of the students. By improving scientific proficiency, students may become scientifically literate members of society. In order to improve the scientific literacy of students, NOS and inquiry should be highly considered in order to accomplish this. True to constructivists, science is best learned actively and through experience.

CHAPTER THREE

ACTION RESEARCH METHODOLOGY

Problem of Practice

The purpose of this study focused on examining the impact of argument driven inquiry on the development of creating evidence-based arguments. Constructivism places an emphasis on hands-on activities, activity-based learning, and students' development of their own structure of thought. Students at XYZ school do an excellent job of passing state tests but struggle to think scientifically. Scientific thinking is when there is uncertainty surrounding an idea and that idea is not believed unless it is supported by evidence or proof. By focusing on the science process skill of argumentation, the needs of students at XYZ school will be addressed with the hope of facilitating their understanding of the NOS and therefore improving their scientific proficiency skills. Critical thinking skills and the ability to argue with evidence are skills that are applicable across a variety of fields. By widening and deepening their understanding of evidence-based arguments, students should be able to apply those skills to real-world situations and improve their content-based knowledge

Research Question

What impact will argument driven inquiry (ADI) have on the development of evidence-based arguments of eight eighth-grade general science students at a public middle school in the Southeast?

Purpose of the Study

The purpose of this study is to examine the impact of argument driven inquiry (ADI) on development evidence-based arguments for eight eighth-grade students enrolled in a regular general science class at a public middle school in the Southeast.

Action Research Design

This action research study was mixed methods in design (Creamer, 2018). A mixed methods approach was more suitable for this research question because the study was looking for a means of improving and increasing the students' understanding and awareness of scientific proficiency, specifically arguing with evidence. Looking for a solution to a problem within a setting is a key characteristic of action research (Herr & Anderson, 2015).

The use of a convergent parallel design was most suitable because qualitative and quantitative data was collected and analyzed separately and then compared and linked during analysis (Creswell & Clark, 2018; Creamer, 2018). Qualitative data collected was in the form of pre and post formal interviews with open-ended questions, observational field notes, and artifacts students submitted. Quantitative data was collected using a comprehension pre-test and post-test, creating an evidence-based argument pre-test and post-test, and an attitudinal Likert scale. Quantitative data can show the basic connection between variables, and the qualitative data shows the details of the meaning of the connections between the variables. Therefore, they draw from each other's strengths and weaknesses to enhance the experimental study (Creswell & Clark, 2018).

Setting and Time Frame of the Study

This study was conducted at a suburban public middle school that serves grades six through eight in a southeastern state. The school and district are known for their top ranking within the state. The researcher will be an insider as a participant and observer for the research since the study will be conducting within her classroom, and the participants are the researcher's students. Class size is twenty-four students. Eight students from one of the researcher's eighth-grade general science class were purposefully selected for this study. Pseudonyms are used throughout the study to protect the identity of the participants and setting.

The time frame for this study was six weeks during third quarter of the 2018-2019 school year. The data gathering process occurred twice a week during the regular sixty-two minute period. The school has an "A" week and a "B" week. During "A" weeks, the class period is during its normal time, 11:35-12:27, which is immediately prior to their lunch period. On "B" weeks, the schedule is flipped, and their class period is from 1:15-2:17, which immediately follows their lunch period.

During week one, all students took a generating an evidence-based argument pre-test, a science content pre-test, and were given a science questionnaire attitudinal Likert scale. Eight student participants were purposefully selected from the evidence-based argument pre-test and science questionnaire. Those selected were then formally interviewed during week one. Over the course of the research period, students participated in two ADI activities. These activities were used as formative assessments and reviewed for content knowledge and the ability to generate an evidence-based argument. Observational field notes were taken during the argumentation phase of the

ADI activities, and artifacts were collected on a regular basis during weeks two through five. During the sixth and final week of the study, post formal interviews were completed, and the comprehension post-test, generating an evidence-based argument post-test, and science questionnaire were administered again.

Participants in the Study

Eight eighth grade students from a general science classroom were purposefully selected to be participants in this study. All students participated in all surveys and assessments, but only the data collected on the eight students chosen to participate in the study was used for research purposes. The eight students selected for data collection were selected based on review of the Likert attitudinal survey and generating an evidence-based argument pre-test.

Specifically, questions one, eight, nine, eleven, and twelve from the science questionnaire were used to select students (See appendix C). These questions were selected because they allowed students to show their confidence in their ability to do well in science and express their opinion about their ability and knowledge of creating an evidence-based argument. Students were then ranked based upon their answers from the survey. The four top and bottom students for each of these questions were then examined further by comparing their answers with their scores on the pre-test for generating an evidence-based argument. The bottom four students and top four students from the Likert attitudinal survey that also scored low on the evidence-based argument pretest were selected as participants for this study. Careful selection of the sample helps to maintain quality of this study (Creswell & Clark, 2018).

Parental consent forms were sent home through email to parents prior to the study to gain permission to participate in the study (Appendix A). Four male and four female students were selectively chosen to be participants. Of the male participants, two were White, one was Latino, and one was Asian. Of the female participants, one was White and three were African American. The researcher has provided a description of each participant. A pseudonym was used for each participant.

Jennifer is a regular education student White female. She is a quiet and conscientious worker. She does try very hard and rarely misses an assignment. She's at the lower end of the eighth grade level with reading and writing. She does not speak up and ask for help when needed.

Emily is a regular education African American female. She is a vocal student when given the opportunity but can also be quiet. She appears to not care to ask for help because it makes her appear that she does not understand something. She is very bright and writes and reads at grade level.

Leslie is a regular education African American female. She is a quiet and conscientious worker. She tries her best in everything that she does but continues to struggle with reading comprehension as well as formal writing. She struggles with grammar and sentence structure as well.

Cathy is a regular education African American female. She is outgoing and has a "bubbly" personality. Academically, she is very low but tries very hard. She struggles in her writing. Her sentence structure and paragraph formation are below grade level as well as her reading comprehension and fluency. Even though she struggles, she doesn't give up.

Garrett is a regular education Latino male. He is outgoing and his work ethic appears to fluctuate. His writing and reading are above grade level. He appears to pick up on ideas quickly and utilizes good organizational techniques in his writing.

Eric is a regular education White male. He suffers from speech apraxia and students often have difficulty understanding him. He has reported being bullied because of his speech difficulty. He is bright but is often not receptive to others' ideas or feedback. His reading comprehension and sentence structure as well as fluency are all on grade level.

Michael is a regular education Asian male. He is a sweet boy who has a tendency to put sports before academics. He appears to struggle to balance both academic and sports. His reading comprehension and writing are at grade level.

Scott is a regular education White male. He appears to put minimal effort into his work and will put forth enough effort to keep a C average even though he is capable of more. Academically, he struggles with writing and with thinking outside the box, but he comprehends well.

Research Methods

Data collection instruments will come from content-based pre- and post-tests, artifacts, attitudinal Likert scale questionnaires, observation field notes, and formal interviews. Pre-tests and post-tests will be developed from the South Carolina Eighth Grade Science Standards for science content knowledge and will be taken from an item bank from the Discovery Education Techbook the school district uses. Items used were selected by the teacher researcher. The generating evidence-based arguments pre- and post-test was based on NGSS standards and teacher created. Using pre-tests and post-tests and formative assessments for assessment data help to monitor student progress and measure how effective a teaching strategy may be (Effron & Ravid, 2013). These ADI activities will help students understand the content, look at empirical data or theories, and show them what is considered scientific knowledge (Sampson & Grooms, 2010). Data collected was used to determine the extent to which ADI helps improve a student's ability to generate an evidence-based argument and on content knowledge gained.

Pre-test/Post-test

A content-based pre-test and post-test about Earth processes and generating an evidence-based argument was administered at the beginning and end of the study. Content-based pre-test and post-test selection-type items were selected by the teacher-researcher from an item bank on Discovery Education Techbook (See Appendix E). Generating an evidence-based argument test consisted of open-ended response questions with a given scenario and data set that were teacher-researcher made (See Appendix D).

Science Questionnaire

Participants were given an attitudinal Likert scale titled "Science Questionnaire" about science composed of twenty questions pre and post study. The survey covers their general feelings about science and their ability to understand and generate evidence-based arguments (See Appendix C). The use of a Likert scale is beneficial because they are efficient to use with data being analyzed quickly and easily (Efron & Ravid, 2013).

Observation/Field Notes

Over the course of the research period, students were given two ADI activities, and both descriptive and reflective observation field notes were taken during the ADI argumentation sessions. Artifacts were collected on a regular basis. The use of descriptive and reflective field notes allows a well-rounded narrative of the classroom (Efron & Ravid, 2013).

Artifact

Artifacts collected included rough drafts of lab reports and final lab reports from each ADI cycle. The lab reports were meant to show the students ability to generate an evidence-based argument. Artifacts are sometimes "the most practical and doable for action research (Efron & Ravid, 2013, p. 123). This is because they are normal occurrences that occur with the practice of teaching and do not require extra time or arrangements to be collected.

Formal Interviews

Students were formally interviewed using open-ended questions about generating an evidence-based argument at the beginning and end of the study in a one-to-one classroom setting. Structured interviews use the same order and identical questions for all participants (Efron & Ravid, 2013). This allows comparable data to be collected among the participants regarding their opinion about generating evidence-based arguments (See Appendix B).

Procedure

Each class period met daily for sixty-two minutes (see Table 3.1). Students were administered a pre-test about Earth Processes on day one of the study. On day two, students were given a science questionnaire attitudinal Likert scale and a pre-test asking them to generate an evidence-based argument. Results from the pre-test about Earth Processes was used for quantitative data to determine the rate of growth for the content. The science questionnaire attitudinal Likert scale and a pre-test asking them to generate an evidence-based argument were used to purposefully select the eight participants for the study. During Wednesday through Friday, each of the participants participated in a structured interview with open-ended questions.

The intervention used was Argument-Driven Inquiry (ADI). ADI was used to address the need for students to improve their ability to think "scientifically" by using the skill of scientific argumentation. The ADI instructional model is devised as a strategy to aid in the development of four key features of scientific proficiency: knowing scientific explanations, using scientific explanations, generating scientific explanations and arguments, and communicating in writing (Enderle, Grooms, & Sampson, 2013). The ADI model has eight stages and is defined by the scope and purpose of each (See figure 3.1). Each stage is equally important, so therefore, they are interrelated and work together with the other steps. ADI is used to help students with the understanding that science is a process and a way of knowing.

Students went through two cycles of creating an evidence-based argument. Each cycle used a different ADI unit. Each ADI cycle lasted fourteen class periods. Descriptive and reflective observations and field notes were taken two days a week during the ADI cycles. During the first cycle, approximately ten to fifteen minutes were spent at the beginning of each stage of ADI to model and teach the stage. The final ADI lab report was assessed using a rubric.

For the second cycle, another ADI unit was introduced, but modeling and teaching of each stage was not implemented. The final ADI lab report was assessed using a rubric. Descriptive and reflective observations and field notes along with artifacts were used to determine the development of the students' ability to create and understand evidence-based argument.

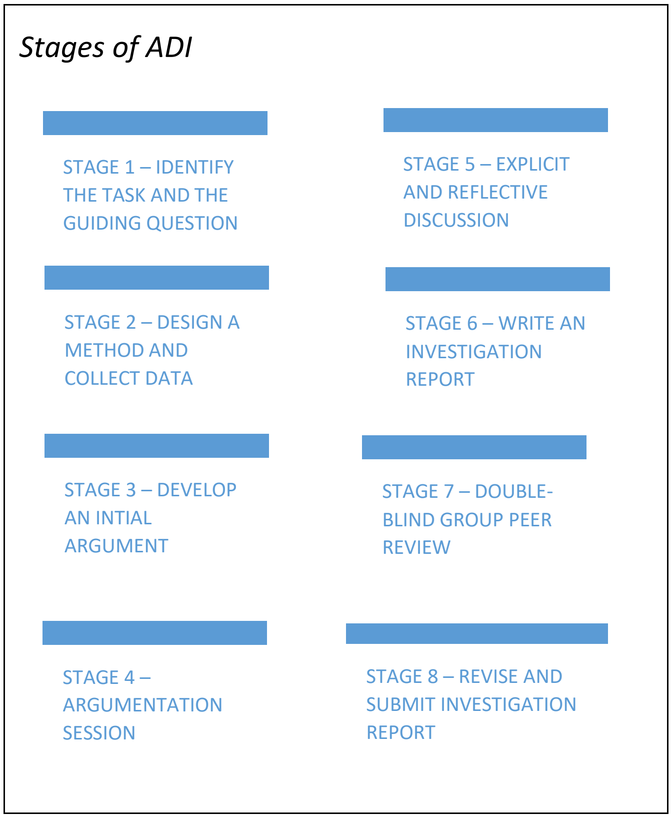

Figure 3.1 – ADI Stages

During the sixth and final week, students were administered the post-test about Earth Processes on Tuesday. On Wednesday, students were given the science questionnaire Likert scale and a post-test about generating an evidence-based argument (see Appendix D). Each of the eight participants also participated in a structured post-interview with open-ended questions Thursday and Friday (see Appendix B).

Table 3.1 – Procedure for Intervention

Week 1	**Description of Daily Activity**
Monday	➢ Earth Processes pre-test administered on-line using Discovery Education.

Tuesday	➢ Administration of science questionnaire attitudinal Likert scale and the pre-test to generate an evidence-based argument.
Wednesday	➢ Formal interview ➢ Start ADI Cycle 1 ➢ ADI Stage 1 – Identify the task and guiding question ➢ Model Stage 1 ➢ Work on Stage 1
Thursday	➢ Formal interview ➢ Review Stage 1 ➢ Start ADI Stage 2 – Design a method and Collect Data ➢ Model ADI Stage 2 ➢ Work on ADI Stage 2
Friday	➢ Formal interview ➢ Work and finalize ADI Stage 2

Week 2	**Description of Daily Activity**
Monday	➢ ADI Stage 3 – Develop an initial argument ➢ Model ADI Stage 3 ➢ Work on ADI Stage 3
Tuesday	➢ Work and finalize ADI Stage 3
Wednesday	➢ ADI Stage 4 – Argumentation Session ➢ Model ADI Stage 4 ➢ Work and finalize ADI Stage 4
Thursday	➢ ADI Stage 5 – Explicit and Reflective Discussion
Friday	➢ Start ADI Stage 6 – Write an investigation report ➢ Model ADI Stage 6 ➢ Work on ADI Stage 6

Week 3	**Description of Daily Activity**
Monday	➢ Work on ADI Stage 6
Tuesday	➢ Work and finalize ADI Stage 6
Wednesday	➢ Start ADI Stage 7 – Double-blind peer review ➢ Model ADI Stage 7 ➢ Work on ADI Stage 7
Thursday	➢ Start ADI Stage 8 – Revise and submit investigation report ➢ Model ADI Stage 8 ➢ Work on ADI Stage 8

Friday	➢ Work on ADI Stage 8

Week 4	**Description of Daily Activity**
Monday	Work and finalize ADI Stage 8
Tuesday	➢ Start ADI cycle 2 ➢ Start ADI Cycle 1 ➢ ADI Stage 1 – Identify the task and guiding question ➢ Work on ADI Stage 1
Wednesday	➢ ADI Stage 2 – Design a method and Collect Data ➢ Work on ADI Stage 2
Thursday	➢ Work and finalize ADI Stage 2
Friday	➢ ADI Stage 3 – Develop an initial argument ➢ Work on ADI Stage 3

Week 5	**Description of Daily Activity**
Monday	➢ Work and finalize ADI Stage 3
Tuesday	➢ ADI Stage 4 – Argumentation Session ➢ Work and finalize ADI Stage 4
Wednesday	➢ ADI Stage 5 – Explicit and Reflective Discussion
Thursday	➢ Start ADI Stage 6 – Write an investigation report ➢ Work on ADI Stage 6
Friday	➢ Work and finalize ADI Stage 6

Week 6	**Description of Daily Activity**
Monday	➢ ADI Stage 7 – Double-blind peer review ➢ Work and finalize ADI Stage 7
Tuesday	➢ Earth Processes post-test administered. ➢ Start ADI Stage 8 – Revise and submit investigation report

Wednesday	➢ Administration of science questionnaire attitudinal Likert scale and the post-test to generate an evidence-based argument. ➢ Work and finalize ADI Stage 8
Thursday	➢ Formal post-interview ➢ Work and finalize ADI Stage 8
Friday	➢ Formal post-interview ➢ Work and finalize ADI Stage 8

Data Analysis

Data collection instruments were used in order to triangulate data. Triangulation uses multiple instruments, so data collection is not limited to one data source, which in turn increases process validity (Herr& Anderson, 2015). Results from interviews, surveys, artifacts, filed notes, and pre/post-tests were utilized. Inductive analysis of the data allowed for emerging patterns and themes to be seen through organizing and coding of the data collected. A comparison joint display was also created from the data collected, and common themes were identified in the results and then compared. Similarities and patterns were observed, as well as contradictory and confounding data. Data collected allowed for reflection of how it related to the PoP and indicated areas that would benefit from additional investigation. Results also gave insight into the impact ADI has on the development of evidence-based arguments, thus answering the research question.

Conclusion

In this study, qualitative and quantitative data was analyzed to determine the impact argument-driven inquiry has the development of evidence-based arguments. Eight eighth-grade students in a public middle school general science class were assessed on their understanding of evidence-based arguments before and after an ADI intervention. ADI is a useful tool in developing evidence-based arguments, but there are challenges with using this intervention.

CHAPTER FOUR

FINDINGS FROM THE DATA ANALYSIS

This mixed methods research study aimed to examine the impact of an Argument-Driven Inquiry (ADI) model on the student development of evidence-based arguments. Students' struggles with arguing with evidence was identified as the problem of practice, which encouraged this study. While students were not having difficulty with content knowledge, they were having difficulty with thinking scientifically. The researcher wondered if using ADI would help students with improving their ability to argue with evidence. This study focused on observing students' development of creating an evidence-based argument using ADI.

During the six-week period of collecting data, a small group of 8^{th} grade students (n=8) participated voluntarily in their general science classroom, with the teacher being the researcher. An authentic atmosphere was created as all activities and data collection took place in the regular classroom. The research study utilized content pre- and post-test, pre and post creation of evidence-based arguments, pre and post Likert attitudinal surveys, reflective and descriptive field notes and observations, artifacts, and pre and post structured interviews. A summary of the findings are presented in this chapter.

Research Question

What impact will argument driven inquiry (ADI) have on the development of evidence-based arguments of eight eighth grade general science students' at a public middle school in the Southeast?

Purpose of the Study

The purpose of this study is to examine the impact of argument driven inquiry on development evidence-based arguments for eight eighth grade students enrolled in a regular general science class at a public middle school in the Southeast.

Findings and Interpretations of Study

During the study, data was collected by the teacher-researcher through content pre- and post-tests (See appendix E) , pre and post generating evidence-based arguments (See appendix D), pre and post science questionnaire Likert scale (See appendix C), pre and post formal interviews (see appendix B), observation/field notes, and artifacts. The science questionnaire was initially studied to look for trends between students that scored high, in the middle, and low on their ability to develop evidence-based arguments. The students' ability to develop evidence-based arguments was measured by two factors: (a) results of pre and post generating evidence-based arguments and (b) student created artifacts. Other data sets were then used to explain why or why not ADI was beneficial to a students' development of evidence-based arguments

After all sources of data were carefully examined to determine if and how ADI impacted the student's development of evidence-based arguments and commonly expressed thoughts and actions could be linked, three themes emerged: (a) confidence level and the ability to develop evidence-based arguments; (b) understandings about the process of scientific argumentation and evidence-based arguments; and (c) recognition of the importance of evidence-based arguments. These three themes appeared to be linked to the students' improvement of their ability to create an evidence-based argument.

Theme One: Confidence Level and the Ability to Develop Evidence-Based Arguments

As the teacher-researcher examined the science questionnaire instrument (see Appendix C), it was used to ascertain students' attitudes and confidence about science. Students self-rated themselves on their general feelings about science and based on that examination, their ability to understand and generate evidence-based arguments could be linked to their confidence level.

The relationship between student self-reported confidence in their ability development of evidence-based arguments was the first theme that emerged. Students who self-reported a higher confidence level generally scored better on the generating evidence-based argument pre and post-tests (See Appendix D) and on the student created artifacts. Students who had a lower confidence level generally scored lower on the generating evidence-based argument pre and post-test and student created artifacts. This trend also held true for the pre and post-formal interviews (See Appendix B).

When looking at the average confidence scores (see Figure 4.1), five out of the eight student participants had an increase in their self-reported confidence levels. (See Questions 1,2,3,4,6,7,8,11,13,16, and 17, from Appendix C). However, Leslie and Garrett's averages decreased, and Scott's confidence level was unchanged.

Leslie and Garrett showed a decrease in their confidence level. Each was remarkable for their own reasons. Leslie had the second largest change of -0.36 in her confidence level. This was significant because she only had a 3-point gain in her generating an evidence-based argument post-test and had minimal gains on her student created artifacts.

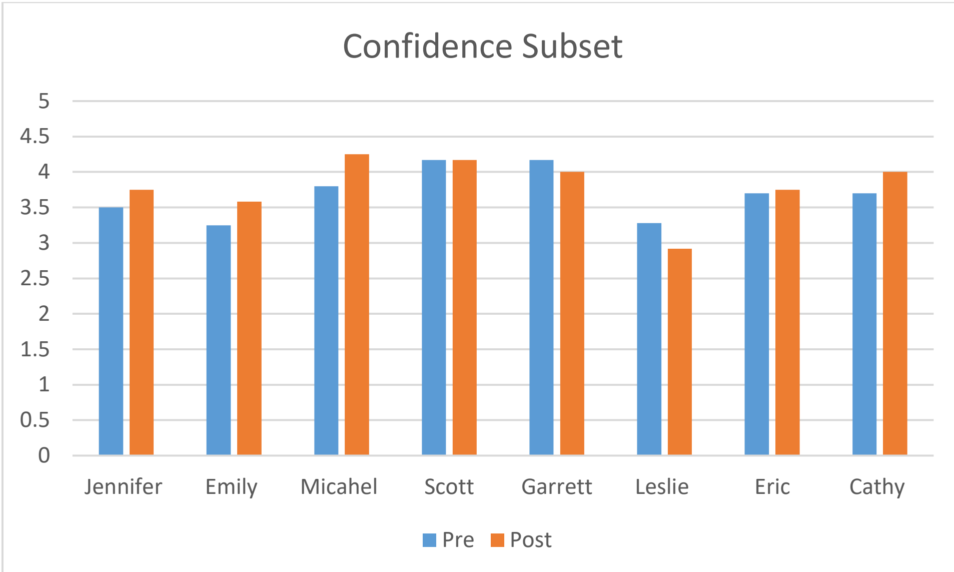

Figure 4.1 - Results of Confidence Subset (See Appendix C, Questions 1,2,3,4,6,7,8,11,13,16, and 17)

The argumentation session is where students share their argument with classmates and review their classmates' arguments. During the argumentation session, Leslie would minimally respond to classmates' questions with, "Yes", "I'm not sure", and "That looks right". Her decreases are consistent though with her involvement in the ADI process, which appeared to be minimal. Due to her lack of substantive participation, it appeared that her confidence level decreased showing a correlation between participation and confidence level.

Garrett on the other hand only showed a slight decrease (-0.17) in his confidence level. However, he gained 10 points (which was the second highest gain) with the generating an evidence-based argument post-test. He scored marginally lower, -3 points, on his student created artifacts. During the argumentation session, Garret was an active participant. For example, he would give constructive feedback to other groups such as, "You need to label your chart and explain what things mean more." For his post-interview, Garrett stated, “I feel like I know more on how to make it better and how to make my evidence stronger.” His decrease in confidence level is contradictory as he did show growth in his ability to develop an evidence-based argument. This contradiction appeared to have been caused by Garrett feeling that as he learned more, he still felt like he had more to learn, thus making him feel insecure in his ability to develop an evidence-based argument.

Scott had no change in his confidence level. He scored slightly higher, +4 points, for the generating an evidence-based argument post-test and gained 11 points on his student created artifacts. During both argumentation sessions, Scott was very passive. For example, in response to a student sharing their claim and evidence, he would not ask questions but would simply say, “Yeah” or “I think you need more evidence.” Scott was unsure about his confidence and was able to verbalize his lack of confidence in his understanding of using claim, evidence, and reasoning to develop and argument. During the post-interview, stated, “It depends on what we are writing about, because there are things I don’t understand. Its increased because of how much time and projects and essays we’ve done with it.” So, while Scott showed growth in his ability to develop an evidence-based argument, he did not feel that he had grown. This could partly be due to his realization of his lack of sustentative participation.

Eric had a modest gain of 0.05 points for his confidence level. Throughout the study, he would often struggle with the ADI process. Eric participated well in the argumentation session, but when it came to writing his lab report, he would rewrite his claim and think that that was evidence and reasoning. He had a disconnect with the difference between a claim, evidence, and reasoning. This did come up in his pre-interview as he responded, “Pretty straightforward as long as it says, “Give evidence for answer A and not B, I’m good” for question 2. During sessions when he was independently writing his rough draft and final drafts, it was noted that Eric would often ask for help but would question suggestions the teacher researcher or other students offered. It was also noted, that he would appear to become belligerent when his ideas were not accepted during most of the ADI stages. This could explain his disconnect because he would appear to refuse suggestions offered to help him connect the relationship between claim, evidence, and reasoning.

Cathy had an increase of 0.3 points for confidence with an overall mean score of a “4” for self-reported confidence. This showed that she felt fairly confident in her ability throughout the entire treatment. However, she showed minimal gains in her overall score and score improvement with both creating and evidence-based argument and with the student created artifacts. During the argumentation sessions, she was an active participant. If a student would ask a question about her group’s poster, she could easily answer it. For example, one student was asking her about their data chart and asked the questions, “How do you know the data is accurate? If they have the same properties, how do you identify them?” Her response was, “You need to test more physical properties. We only did the three but know that we need to go back and test another one or two properties.” During the post-interview, Cathy stated, “You have to use actual evidence and it has to be facts.” This data is contradictory to the other student-participants. Those that had a higher confidence level typically showed more gains than those that had a lower confidence level. This contradiction appears to have occurred because Cathy appears to be below grade level in her writing ability. Therefore, while she was able to verbalize her ability to develop an evidence-based argument, she showed difficulty in producing it in written form.

During the pre-interview, seven out of the eight students stated that they felt comfortable reviewing another classmate's idea. Scott stated, "It is good experience to review other people's ideas, and it can help you." Cathy stated, "Cuz I feel ideas are always different from others so I can reflect off theirs." Eric was the only student who stated he did not feel comfortable. He stated, "Not really because I do not think it will be safe to challenge other people's ideas at school." Due to Eric's speech issues and experiencing bullying in the past, it was understandable that he would feel tentative about this process.

For the post-interview, all students were articulate in how ADI was different than prior experiences that asked them to support a claim with evidence. Post-interview responses revolved among the participants around three ideas: one needs to use more support for answers, one need to use facts, and ADI is more descriptive. For example, Michael stated, "You have to support your answers even more to show where you get that answer and why you support it." Emily stated, "It's easier because it gets more evidence to help me support my claim."

Continuing with the post interview, seven out of the eight students responded that they felt more confident to make a claim and support it with evidence. Jennifer stated, "Well, at first I wasn't trying to figure it out and made up something. When you add the charts and stuff, it helps more."

All students responded that they felt more comfortable reviewing another classmate's idea. Eric had responded during the pre-interview that he was not comfortable and didn't feel safe challenging another student's idea. For the post-interview, he stated, "Yes. Because… I don't really know."

Overall, the first emerging them theme, confidence level and the ability to develop evidence-based arguments, reveal that the more confidence a student had in their ability to generate an evidence-based argument, the greater their understanding of evidence-based arguments and feeling that generating an evidence-based argument is important.

Theme Two: Student Understanding of the Process of Scientific Argumentation

The second theme to emerge was the student understanding about the process of scientific argumentation and evidence-based arguments. From the science questionnaire, questions 5,10,12,14,15,16,17, and 18 (See Appendix C) were relevant to the students' understanding of the theme.

The results from the understanding argumentation and evidence-based arguments subset (see Figure 4.2) showed that seven out of the eight student participants self-reported a marginally better understanding of scientific argumentation and evidence-based arguments after the treatment. Pre-treatment, participants had a mean self-rating of 3.14 for these questions. Post treatment, the mean self-rating was 3.51. This suggests that they were neutral in their understanding about the process of scientific argumentation and evidence-based arguments. This is significant because when looking at the results of pre and post generating an evidence-based arguments (See Appendix D) and student created artifacts that were used to measure a students' ability to develop evidence-based arguments, the students who self-rated themselves the lowest actually scored highest or in the higher range relative to the submitted student artifacts.

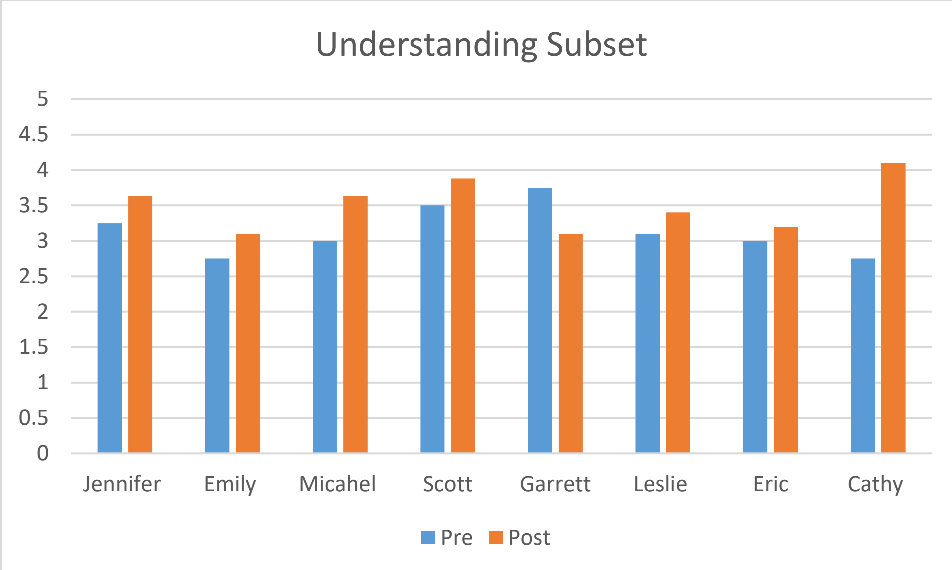

Figure 4.2 - Results of Understanding Subset (See Appendix C, Questions 5,10,12,14,15,16,17, and 18)

For example, Garrett reported a decrease in understanding and Cathy had the largest self-reported improvement for understanding. Garrett's mean self-rating gain was a -0.65 points which meant that he felt that he understood more prior to the treatment than after the treatment. He had the second largest gain on the post-test of creating an evidence-based argument, the highest score on that instrument of a 16, and had the highest scores on both student created artifacts (lab-reports). This also corresponded with his pre-interview response to question 2, "Makes sense because I know what they all mean and how they correspond with each other."

The pre and post creating an evidence-based argument (see Appendix D) was used to measure a students' ability to develop evidence-based arguments. The mean score of the pre-assessment was 5.62 points out of a possible 20 points. The mean score of the post-assessment was 11.125 points. The mean gain was 5.5 points. The student with the largest gains of twelve points was Jennifer. She also had a self-rating gain of 0.4

which showed she felt that she had a slightly better understanding of evidence-based arguments. Garrett also showed a significant gain of ten points.

Cathy had the lowest score out of all eight student-participants on the generating an evidence-based argument tests and had a total score of seven out of a possible twenty points for the student created artifacts (lab reports). She was also the only student that self-rated a mean score of 4.1 for the importance subset. For her post interview, she was very well-spoken about her explanations. For example, when asked about the importance of providing evidence to support a claim, her response was, “You can’t say something and not have facts to back it up because folks might not believe it.” She also responded when asked if using ADI helped to improve her ability in developing evidence-based arguments, “Yes, because I learned from my mistakes. Now when I do rough drafts, I look over it and try to get more information to sound better.”

Similar to the first theme, Cathy agreed that she had an understanding about the process of scientific argumentation and evidence-based arguments, but she showed the least growth on the generating an evidence-based argument test and on the student created artifacts. This again could be attributed to her appearance of writing at below grade level which could lead to her written expression not matching her verbal expression. Cathy is not writing or reading at grade level, so that could have an effect, as all scored instruments (with the exception of the content pre-test and post-test) were written. That would explain why she felt like she understands the process of scientific argumentation and evidence-based arguments, but her scores do not reflect it.

The student created artifacts were the second instrument used to measure a students’ ability to develop evidence-based arguments. Student created artifacts collected included the rough drafts and the final drafts of the lab reports. Both were graded using a pre-made rubric. Each individual part (claim, evidence, reasoning) of an evidence-based argument was evaluated.

For the claim, five out of the eight students had growth in ADI cycle 1 on their development of a claim. For example, Garrett's initial claim was incomplete, "These harmful earthquakes occur in the convergent plate and can really damage where ever it is." For his final draft, he made sufficient changes to his claim and it read, "Earthquakes with a greater magnitude are more likely to occur at a convergent boundary because of the plates colliding with each other." Leslie and Cathy showed no growth, as they did not attempt to rewrite their claim.

Two students showed growth in ADI cycle 2 on their development of a claim. However, four students were scored proficient in the rough draft stage of their lab report and wrote a sufficient claim. Michael was awarded no points for his claim in both the rough and final draft as he did not attempt a claim in his rough draft but rather stated his evidence only. For the final draft, he again did not attempt a claim, but he included evidence and reasoning. This could be in part, because of Michael's appearance of not accepting or listening to help when he feels like he understands something.

Gain for including evidence showed a change between ADI cycle 1 and 2. Cycle 1 evidence had two student-participants, Scott and Garrett, that were proficient at presenting evidence. Jennifer did not present any evidence in the rough draft but presented proficient evidence in the final draft. Her reasoning was, "I didn't feel like writing all that in the beginning cuz it wasn't making sense." Eric and Michael presented irrelevant evidence in the rough and final draft. Four students were rated by the researcher as being proficient in presenting evidence for the final draft.

For ADI Cycle 2 evidence, students showed little change in the evidence presented. Only one student, Garrett was rated proficient for the final draft. The seven other students were rated “partially”, meaning evidence presented needed to be explained more.

Reasoning for ADI cycles 1 and 2 also showed change. For cycle 1, two students out of the eight were rated as proficient for the final draft. Two students provided partial reasoning (justification for the evidence) for the final draft, and four students were unable to provide reasoning (justification for the evidence) in both the rough draft and final draft.

For ADI cycle 2, three student participants were unable to produce reasoning for the rough draft. Seven out of the eight students were able to provide partial reasoning (justification for the evidence) for the final draft. One student was considered proficient at presenting reasoning for the final draft.

The overall mean ADI cycle 1 score was 3.375 points out of a possible 6 points. The mean ADI cycle 2 score was 3.625 points out of a possible 6 points. Three students (Garrett, Jennifer, and Michael) showed no change between cycles. Garrett scored all 6 points for both cycles, so there was no potential gain. Leslie, Eric, and Cathy had a modest 1 point gain. Emily and Scott showed a -1 point gain.

The fourth instrument used was individual structured formal interviews (see Appendix B). Students were interviewed at the beginning and end of the treatment. The pre- and post- interviews asked very similar questions about the importance of parts of evidence-based arguments and scientific argumentation. The pre-interview also asked about their experience and understanding of evidence-based arguments. The post-interview asked about their experience using ADI for developing evidence-based arguments. The interviews gave better insight into the attitudes students had about evidence-based arguments.

Seven out of the eight students reported having experience with evidence-based writing in the pre-interview. Leslie stated, “I don’t remember.” Most remembered doing it but could not recall details from the assignments. Five out of the seven students agreed that the terms claim, evidence, and reasoning make sense. Scott stated, “Not that confusing but sometimes it is hard to explain it out good.” Jennifer stated, “Sometimes. Like sometimes I get stuck on a question.” The information from these first two question indicated that students were familiar with evidence-based arguments but had difficulty explain what they are.

When asked about what scientific argumentation meant to the student, three main answers were given: background evidence and reasoning, arguing why they chose the answer, and going back and forth with science. Jennifer stated, “Nothing.” Six out of the eight students felt that scientific argumentation is different than regular conversational argumentation. Garrett stated, “Scientific argumentation you use evidence that you get scientifically based on facts and conversational is your opinion and proving it’s right.” Leslie stated, “Scientific argumentation is like when you have to make an argument about what you are learning. Conversational arguments it is against two people.” Michael stated, “You have to give more detailed evidence and use more fancy words. Emily stated, “No, because in both you are both explaining your reasoning. Cathy stated, “Not really. I mean it’s just science and you are arguing over one idea.”

The theme of student understanding of evidence-based arguments was the most confounding as students self-reported minimal improvement in their understanding of evidence-based arguments, but understanding of evidence-based arguments in the other measures showed that their understanding improved. This is one area that needs further research.

Theme Three: Students’ Feelings About the Importance of Evidence-Based Arguments

The third and final theme to emerge was the student’s feeling towards the importance of evidence-based arguments. From the science questionnaire, questions 9, 19, and 20 (See Appendix C) were relevant to the importance of evidence-based arguments theme. The students who felt strongest about the importance of evidence-based arguments did better overall. This could indicate that if a student felt like the task is important, they put forth more effort.

The results from the importance of argumentation and evidence-based arguments subset (see Figure 4.3) showed that five out of the eight students felt stronger about the importance of argumentation and evidence-based arguments. For example, Michael self-rated the highest with a mean of 4.25. He was active during the argumentation sessions. He would ask the teacher-researcher for clarification if a claim was written correctly, to explain how to justify evidence, and how to set up a data table. He also stated during

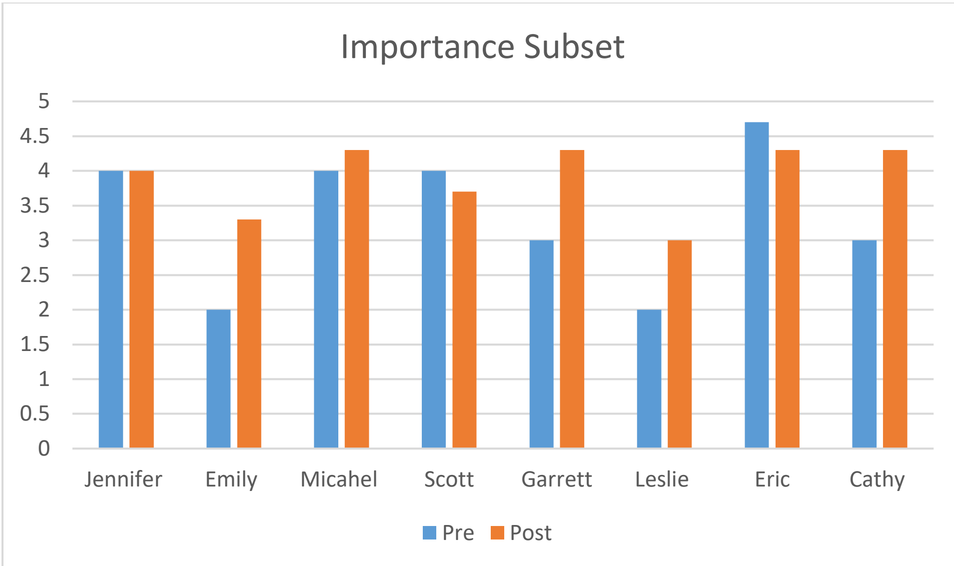

Figure 4.3 Results of Importance Subset (See Appendix C, Questions 9, 19, and 20)

both interviews, "It is important to justify your evidence, so people believe you and what you say. You want to have proof for what you say." Michael also had the highest gain in the student created artifacts. While he only had a +5-point gain in the generating an evidence-based argument, he scored the highest out of all the participants.

Garrett had one of the overall highest-earned scores with the generating evidence-based argument pre and post-test and lab reports and self-reported himself with a mean score of 4.3 on the 5-point scale. He was active in the ADI process. During the argumentation session, he would say things such as, "Ok. If we look at the rose quartz in the chart, we can see that it could scratch the glass, just like our sample. That was the only one that could scratch the glass so that must be it. What do you think?" For the post-interview, he stated, "Argumentation is super important because it helps you prove your point. You want people to believe what you say is right." So, his self-rating also follows the third theme.

Emily and Cathy both had a gain of 1.3 points in the self-ratings. This is significant because both students showed minimal gains with the generating an evidence-based argument tests and with the students created artifacts. As stated in the previous themes, Cathy grew overall in the process in a verbal fashion but not with her written expression. Emily changed from feeling that evidence-based arguments were not too important, to feeling a little stronger than neutral about them. This was interesting because in her post-interview she rated the importance of a justified claim a 4 and said, "Yeah, it is important because you need to explain yourself."

Leslie self-rated a 3, which was an increase from a 2 before treatment. This meant that she went from feeling that generating an evidence-based argument was not too important to feeling neutral. She scored low on all instruments used to measure the development of evidence-based arguments. Leslie is a very shy student and prefers the peer-editing step of ADI compared to the argumentation session. Her responses were limited to her peers in the argumentation sessions and would respond with simple phrases such as "Yes", "I think so" and "Yeah". However, during the peer-editing, she would leave detailed written comments to her peers such as, "You have a good claim, but you did not support it with enough evidence." Therefore, it appears that she was beginning to change her opinion about the importance of evidence-based arguments.

Scott and Eric both showed a slight decrease in their self-rating about the importance of evidence-based arguments. Scott's decrease was confounding as he showed no indication, with any of the instruments, that he felt evidence-based arguments were less important that at the start of the treatment. Eric though, showed frustration throughout the ADI process. During the argumentation phase he would often voice this frustration by going to the teacher-researcher and saying, “No one will listen to me or my ideas.” He also would argue with the teacher-researcher, “I am supporting my claim with evidence.” This frustration would appear to have changed Eric’s thoughts about the importance of evidence-based arguments because his prior knowledge about them had been challenged.

The pre and post-test on Earth Processes content (see appendix E) looked at a student’s ability to demonstrate gains in content knowledge. The mean pre-test score was 27.59%; the mean post-test score was 47.43%, with 19.84 points as the increased mean value from pre-test to post-test. Garrett showed the biggest gain of 30.8 points. Leslie had the smallest gain of 11.6 points, and Jennifer also had a minimal gain of 13.8 points. Both students rushed through the post-test and indicated to the researcher that they did not “try hard that day” and were “tired of taking tests.” Students were also aware, and Leslie, Scott, Cathy, and Jennifer stated, “since it didn’t count for a real grade, they didn’t try very hard.”

This idea that working for grades is what matters was relevant throughout all areas. The student-participants often asked throughout the treatment if something would count for a grade, and they would appear to work harder when it did. For example, some participants would put little effort into the peer editing process and the argumentation sessions, as they were only “steps” in the process and did not count towards their final grade.

All students rated the importance of providing evidence to support claims with a four or five. They supported their rating with two main ideas: supporting their reasoning and wanting to “back-up” their claim. When asked to rate the importance of providing justification for the evidence used, seven rated it a four or five; but Eric rated it a three – four stating, "because without justification, someone could come around and say something else." This indicated a potential problem that while students stated the terms claim, evidence, and reasoning, make sense, they confused the meaning of these words.

All students rated the importance of providing evidence with a claim and providing justification for evidence used with a four or five. The common response for the importance of providing evidence to back up a claim was about the need to back up your claim. The common response for providing justification for evidence used was that it is necessary to explain the evidence, so it shows how the evidence supports the claim.

The theme of importance can be extended to include self-importance of the process. More research needs to be conducted on motivation for critical thinking when it is does not affect their grade.

Conclusion

Analysis of the data showed evidence of a positive impact ADI can have on helping a student develop evidence-based arguments. Data collected from the student-participants demonstrated an increase in a student's ability to develop evidence-based arguments. Student gains were not consistent, but all showed some improvement. Students' confidence in their ability to produce and develop evidence-based arguments played a role. The teacher-researcher also noted that it was common for students who were showing large improvements to start questioning their ability to understand the process and thus rate themselves lower, as they felt they did not understand. Students who indicated they felt scientific argumentation was important tended to do better overall. The teacher-researcher observed an increase in the participation of the student-participants when they felt it was important. While no correlation was determined between ADI and content improvement, all students experienced a gain in their post-test content scores. In the following chapter, a summary of the study will be provided. An action plan for the teacher-researcher's classroom will be provided as well as suggestion for further research.

CHAPTER FIVE

DISCUSSION, IMPLICATIONS, AND RECOMMENDATIONS

Introduction

In the researcher-teacher's classroom, students would appear to be scientifically proficient and literate, as they score well on standardized tests. However, what the students struggled with was the critical thinking piece of scientific literacy, specifically arguing with evidence, which led to the Problem of Practice for this study. Teaching the NOS has become the prominent theme for science education as it is considered a characteristic of scientific literacy (Bell, 2009). Scientific literacy studies and breaks science into three domains: a body of knowledge, a set of methods and processes, and way of knowing (Bell, 2009). The researcher-teacher acknowledged that her students had the body of knowledge, but they were limited on their ability of understanding science as a set of methods and processes and a way of knowing. In order for a student to have scientific proficiency, they also must be scientifically literate.

This mixed methods research study was conducted to observe the impact of ADI on a students' development of scientific proficiency, specifically generating evidence-based arguments. ADI was chosen as the intervention to use because it helps the students' understanding of the NOS and it helps improve their science process skills. The findings of this study revealed three themes: confidence level and the ability to produce evidence-based arguments, understandings about the process of scientific argumentation and evidence-based arguments, and recognition of the importance of evidence-based arguments. These three themes were linked to the students' improvement of their ability to create an evidence-based argument.

This study may benefit other classrooms by emphasizing barriers that may impact a student's ability to create an evidence-based argument. Critical thinking difficulties were a school-wide concern because district educational goals include preparing 21st century learners. Our students have minimal comprehension issues with science content; but if critical thinking skills are not addressed, we are failing our students.

Research Question

What impact will argument driven inquiry (ADI) have on the development of evidence-based arguments of eight eighth grade general science students at a public middle school in the Southeast?

Purpose of the Study

The purpose of this study is to examine the impact of argument driven inquiry on the development evidence-based arguments for eight eighth grade students enrolled in a regular general science class at a public middle school in the Southeast.

Summary and Implications of the Study

This study evaluated eight student-participants over a six-week period by collecting data during the third quarter of the 2018-2019 school year at a suburban middle school in the Southeast. The eight student-participants participated in two Argument-Driven Inquiry (ADI) cycles. Quantitative and qualitative data were collected throughout the study. Quantitative data was collected from content pre- and post-tests, a science questionnaire Likert scale, a pre- and post-generating an argument test, and artifacts (rough and final drafts of the lab reports). Qualitative data included pre- and post-structured formal interviews and field notes/observations.

Throughout this action research study, ADI was used to assess if it was a useful model to develop scientific proficiency, specifically arguing with evidence.

Several implications were consequent of this study:

(1) ADI can help develop a student's ability to generate an evidence-based argument;

(2) Student confidence may determine the extent of development of an evidence-based argument;

(3) Student acceptance of believing in the importance of generating an evidence-based argument may influence the rate of development.

Students' growth in their development of evidence-based arguments was determined by looking at two factors: (a) results of pre and post creating of evidence-based arguments and (b) student created artifacts. While no student achieved a perfect score with either of these factors, most student showed a gain. Students that showed an increase in confidence generally had a higher gain than those that had minimal or no increase.

However, it is worth noting that one student lost confidence according to the science questionnaire but had a gain relative to what was reveled through the submitted artifact data set. Another student had a high increase in confidence, according to the science questionnaire and post-interview but had a negative gain through the submitted artifact data set. This implies one of two things: 1). as a student's confidence in their ability to generate an evidence-based argument improves, their ability also improves, and

2). a student may have the perception of gaining confidence, but in reality show little or no growth, indicative of the submitted student artifacts due to below-grade-level writing skills. This lack of confidence in their writing inhibited them to articulate what they know.

It is also worth noting that students who indicated that evidence-based arguments were important showed greater gains. That is, when students "bought into" the process of ADI and understood the need to use evidence, they were more engaged in the entire process and appeared to put forth more effort. Overall, the research question was answered, and ADI was shown to be a helpful intervention in the development of the student-participants scientific proficiency.

This study took place in a suburban school with excellent resources, and the participants demonstrated that their perception of what they know is directly related to how well they did with ADI. ADI is just one intervention that can be used to teach the Nature of Science (NOS) and create that authentic science learning environment. But if students are not given these opportunities to explore and learn about the NOS in an authentic way, there is a potential of losing the talent these students may offer as they become adults.

Moreover, for underserved/under-resourced populations and those that have been historically marginalized, it is all the more critical that teachers be aware of teaching NOS because these students are already short-changed for a variety of reasons, including by the system itself. In short, there is a need to heighten our awareness for these students, as we are losing the potential talent among them.

Teaching the NOS can help to improve enthusiasm for the students because it helps to create an authentic learning environment for science. “It is *the way we teach* that profoundly affects the way that students perceive the content of that curriculum” (Ladson-Billings, 2009, p. 15). Teaching science in a meaningful way is what will help students and not lose them. As a result of this study, being a science teacher is not just teaching content knowledge and NOS but also using models that foster critical thinking/critical thought.

Unfortunately, there is little research on how well educators, themselves, understand NOS. If educators do not have developed conceptions of NOS, it is difficult to transfer that knowledge to their students (Lederman, Abd-El-Khalick, Bell, & Schwartz 2002; Lederman, 1999; Herman, Clough, & Olsen, 2013; Wong, Firestone, Ronduen, & Bang, 2016). The aim of science education has been to teach the NOS, but unfortunately, that aim is often not being met and science classrooms are often still being taught in a traditional manner.

While generalizations cannot be made, the way we teach science needs to be examined. Student perception of their ability is often different than the terms of their actual production of work. This is something that starts in elementary school, as research suggests. The way science is taught from an early age has a direct impact on the student’s success in science as they get older (Enderle, Grooms, & Sampson, 2013). Therefore, teaching NOS is critical to the development of scientific proficiency and teachers need to be educated in a way to develop their understanding of the NOS so that they can help students become scientifically proficient.

Action Plan

The results of this action research study showed the ADI had a positive impact on the development of scientific proficiency. The teacher research will continue to use this strategy for regular classroom instruction. To build upon success of the study, the teacher-researcher has developed an action plan, not only for the teacher-researcher's classroom but throughout the school's science classrooms that consists of three phases:

(1) Conduct and share additional research using ADI;

(2) Share the findings with colleagues; and,

(3) Conduct future research with other grade levels in the building.

The first phase of the action plan is to conduct additional research using ADI in her classroom. ADI was shown beneficial to help improve one area of scientific proficiency and the researcher would like to observe the results if ADI is used thought the entire course for her Eighth-grade science students.

The second phase is to present the findings with colleagues in the building at the beginning of the school year. This will allow the teacher-researcher to share her positive findings on ADI and its impact on scientific proficiency. The goal of this phase is to introduce the other grade level teachers to ADI so that it can become implemented over a two-year period and used in all the science classrooms within the teacher-researcher's building.

The third phase is to conduct future research with other grade levels in the building. It is likely that by researching how to implement ADI across various grade levels, students will continue to develop their critical thinking skills, scientific proficiency, and understanding of the NOS.

Suggestions for Future Research

Action research is rooted help develop a practical solution to a problem observed in an educational setting (Herr and Anderson, 2015). As a result of this action research study, the teacher-researcher noted four areas that could benefit from further research regarding the use of ADI to improve scientific proficiency:

(1) Conducting the same research over a longer time;

(2) Conducting the same research using a different demographic population;

(3) Studying the link between content knowledge and creation of evidence-based arguments; and

(4) What strategies could be used for building and maintain sustained engagement.

While results did lean towards ADI positively impacted students' development of scientific proficiency by improving their ability to generate and argument, gains were limited. Conducting the research over a longer time period, such as two quarters or an entire school year, would allow for the researcher to determine if consistent use of ADI would impact the students to a greater extent.

As with action research, this study was conducted to give an answer to a specific group of students and not be generalizable. Overall, science education in our country should be aimed towards improving the understanding of the NOS but students still show a gap in their understanding of NOS. At the students' school, the demographic population is typical of many suburban schools and the students' ability to preform well on content knowledge on standardized state test is also common for this group.

Conducting this research with a different demographic group is research that should be considered.

If science is considered a process and a way of knowing, content knowledge is necessary, but content knowledge is just one facet of being scientifically proficient. Research could be conducted to see if students with better content knowledge are able to create better evidence-based arguments.

Finally, it was noted in the study about students feeling that creating evidence-based arguments was important. Those who felt it was important saw more growth in their develop of evidence-based arguments. Motivation is linked to engagement and if a student does not feel that something is important, be it receiving a grade or finding it useful later in life, they tend to show less growth. Therefore, it would be beneficial to research what strategies can be used with ADI for building and maintaining sustained engagement.

Conclusion

This study examined the impact of ADI on eight eighth grade middle school students' development of scientific proficiency, specially the development of evidence-based arguments. Scientific proficiency is one part of NOS and this continues to be a theme for science educators. However, for various reasons, many science educators are not teaching the NOS but still teach science in a traditional manner. By teaching this way, students are gaining content knowledge but are missing the other two domains of being scientifically literate: a set of methods and processes and way of knowing (Bell, 2009). Giving students an opportunity to "do" science in a way that reaches all three domains of science literacy is essential.

As civilization continues to become technologically and scientifically advanced, people are hearing more about these advances in media outlets. Carl Sagan (1990) stated, “We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology. This is a clear prescription for disaster” (p. 264). If our role as educators is to produce students who will be competent citizens that can be successful in a global environment, science education should be at the forefront of producing scientifically literate and proficient students.

REFERENCES

Akkus, R., Gunel, M., & Hand, B. (2007). Comparing an inquiry-based approach known as the science writing heuristic to traditional science teaching practices: Are there differences? *International Journal of Science Education, 29*(14), 1745-1765. doi:10.1080/09500690601075629

Allchin, D. (2011). Evaluating knowledge of the nature of (whole) science. *Science Education, 95*(3), 518-542.

Anderson, R. D., (2007). Inquiry as an organizing theme for science curricula. In S. K. Abell & N.G. Lederman (Eds.), *Handbook of research on science education* (pp. 807-830). Mahwah, NJ: Lawrence Erlbaum Associates.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory.* Englewood Cliffs, NJ: Prentice Hall.

Bell, R. (2009). Teaching the nature of science: three critical questions. Retrieved April 18, 2017, from http://ngl.cengage.com/assets/downloads/ngsci_pro0000000028/am_bell_teach_nat_sci_scl22-0449a_.pdf

Berkovitz, J. (2017). Some reflections on "going beyond the consensus view" of the nature of science in K- 12 science education. *Canadian Journal of Science, Mathematics and Technology Education*, *17*(1), 37-45.

Berland, L., & Reiser, B. (2009). Making sense of argumentation and explanation. *Science Education 93* (1): 26-55.

Capps, D. K., & Crawford, B. A. (2013). Inquiry-based instruction and teaching about nature of science: Are they happening? *Journal of Science Teacher Education, 24*(3), 497-526.

Chang, S. (2008). The learning effect of modeling ability instruction. *Asia-Pacific Forum on Science Learning & Teaching, 9*(2), 1-21.

Çibik, A. S. (2016). The effect of Project-Based history and nature of science practices on the change of nature of scientific knowledge. *International Journal of Environmental and Science Education, 11*(4), 453-472.

Crawford, K. (1996). Vygotskian approaches in human development in the information era*. Educational Studies in Mathematics*, 3143-3162. doi:10.1007/BF00143926

Creamer, E., G., (2018). *An introduction to fully integrated mixed methods research.* Los Angeles: Sage.

Creswell, J.W. and Plano Clark, V. L. (2018). *Designing and conducting mixed methods research (*3rd edition). Los Angeles: Sage.

Demircioglu, T., & Ucar, S. (2015). Investigating the effect of argument-driven inquiry in laboratory instruction. *Educational Sciences: Theory and Practice, 15*(1), 267-283.

Devlin, T., Feldhaus, C., & Bentrem, K. (2013). The evolving classroom: A study of traditional and technology based instruction in a STEM classroom. *Journal of Technology Education, 25*(1), 34-54.

Dewey, J. (1938). *Experience and education*. New York: Collier Books.

Duckworth, E. (1987). '*The having if wonderful ideas' and other essays on teaching and learning.* New York: Teachers College Press.

Enderle, P., Grooms, J., & Sampson, V. (2013). The use of argumentation in science education to promote the development of science proficiency: a comparative case study. Retrieved April 18, 2017, from http://files.eric.ed.gov/fulltext/ED564062.pdf

Efron, S., Ravid, R. (2013). *Action research in education: A practical guide*. New York: Guilford Press.

Fallik, O., Eylon, B., & Rosenfeld, S. (2008). Motivating teachers to enact free-choice project-based learning in science and technology (PBLSAT): Effects of a professional development model. *Journal of Science Teacher Education, 19*(6), 565-591. doi:10.1007/s10972-008-9113-8

Grooms, J., Enderle, P., & Sampson, V. (2015). Coordinating scientific argumentation and the next generation science standards through argument driven inquiry. *Science Educator, 24*(1), 45-50.

Gunn, T., & Pomahac, G. (2008). Critical thinking in the middle school science classroom. *International Journal of Learning, 15*(7), 239-247.

Herr, K., & Anderson, G. (2015). *The action research dissertation: A guide for students and faculty* (2nd ed.). Los Angeles: Sage.

Herro, D., & Quigley, C. (2017). Exploring teachers' perceptions of STEAM teaching through professional development: implications for teacher educators. *Professional Development in Education, 43*(3), 416- 438. doi:10.1080/19415257.2016.1205507k

Herman, B. C., Clough, M. P., & Olson, J. K. (2013). Association between experienced teachers' NOS implementation and reform-based practices. *Journal of Science Teacher Education, 24*(7), 1077- 1102.

Irzik, G., Nola, R. (2011) A family resemblance approach to the nature of science for science education. *Science & Education, 20*(7-8). 591- 607.

Jackson, J., Dukerich, L., & Hestenes, D. (2008). Modeling instruction: An effective model for science education. *Science Educator, 17*(1), 10-17.

Keys, C. W., Hand, B., & Prain, V. (1999). Using the science writing heuristic as a tool for learning from laboratory investigations in secondary science. *Journal of Research in Science Teaching, 36*(10), 1065-1084. doi:10.1002/(SICI)1098-2736(199912)36:103.0.CO;2-I

Kim, H., & Song, J. (2005). The features of peer argumentation in middle school students' scientific inquiry. *Research in Science Education, 36*(3), 211-241.

Ladson-Billings, G. (2009). The dream keepers: Successful teachers of African American children. San Francisco, CA: Jossey-Bass.

LeBlanc, J., Cavlazoglu, B., Scogin, S., & Stuessy, C. (2017). The art of teacher talk: Examining intersections of the strands of scientific proficiencies and inquiry. *International Journal of Education in Mathematics, Science and Technology, 5*(3), 171-186.

Lederman, N. (1999). Teachers' understanding of the nature of science and classroom practice: factors that facilitate or impede the relationship. *Journal of Research in Science Teaching, 36*(8), 916-929.

Lederman, N., Abd-El-Khalick, F., Bell, R., & Schwartz, R. (2002). Views of the nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6), 497-521.

Lederman, N., Antink, A., & Bartos, S. (2012). *Nature of science, scientific inquiry, and socio-scientific issues arising from genetics: a pathway to developing a scientifically literate citizenry, 23*(2), 285-302. doi:10.1007/s11191-012-9503-3

Lederman, N., Lederman, J., & 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.

Lotter, C., Smiley, W., Thompson, S., & Dickenson, T. (2016). The impact of a professional development model on middle school science teachers' efficacy and implementation of inquiry. *International Journal of Science Education, 38*(18), 2712-2741. doi:10.1080/09500693.2016.1259535

McConnell, T., Parker, J., & Eberhardt, J. (2013). Assessing teachers' science content knowledge: A strategy for assessing depth of understanding. *Journal of Science Teacher Education*, *24*(4), 717-743. doi:10.1007/s10972-013-9342-3

McHenry, N., & Borger, L. (2013). How can teacher-directed professional development lead to the identification, utilization, reflection on, and revision of 5E learning progressions? *Electronic Journal of Science Education, 17*(1), 1-24.

Mertler, C. A. (2014). Action research: Improving schools and empowering educators. Los Angeles, CA: Sage.

Minogue, J., Madden, L., Bedward, J., Wiebe, E., & Carter, M. (2010). The cross-case analyses of elementary students' engagement in the strands of science proficiency. Journal of Science Teacher Education, 21(5), 559-587.

Myeong-Kyeong Shin, M., & Jeonghee, N. (2012). Exploring changes found in lab reports of pre-service science teachers by adapting a group questioning strategy with using the science writing heuristic template. *Mevlana International Journal of Education, 2*(2), 33-42.

Na, J. J., & Song, J. J. (2014). Why everyday experience? Interpreting primary students' science discourse from the perspective of John Dewey. *Science & Education, 23*(5), 1031-1049. doi:10.1007/s11191-013- 9637-y

National Commission on Excellence in Education. (1983). *A nation at risk*. Washington, DC: Congressional Research Services.

National Research Council. (1996). *National science education standards.* Retrieved from http://books.nap.edu/html/nses/pdf/index.html.

NGSS (Next Generation Science Standards) Lead States. 2013. *Next Generation Science Standards: For States, By States.* Washington, DC: The National Academies Press.

Nicholl, B. (2009). The epistemological differences between a teacher and researcher: A personal journey illustrating second order action research. *Design and Technology Education, 14*(3), 21-36.

Olivia, P.F., & Gordon, W.R. (2013). *Developing the Curriculum*. Boston, M: Pearson.

Sagan, C. (1990). Why we need to understand science. *The Skeptical Inquirer, 14*(3), 263-269. Retrieved from https://skepticalinquirer.org/1990/04/why_we_need_to_understand_science/?%2Fsi%2Fshow%2Fwhy_we_need_to_understand_science

Sampson, V., & Grooms, J. (2010). Generate an argument: an instructional model. *Science Teacher, 77*(5), 32-37.

Sampson, V., Grooms, J., & Walker, J. (2011). Argument-Driven Inquiry as a way to help students learn how to participate in scientific argumentation and craft written arguments: An exploratory study. *Science Education, 95*(2) 217-257.

Sampson, V., Murphy, A., Lipscomb, K., & Hutner, T. (2018) *Argument-Driven inquiry in earth and space science*. Arlington, Virginia; NSTA Press.

Schiro, M. S. (2013). *Curriculum theory.* (2nd ed.). Los Angeles, CA: Sage.

Schwartz, R., Lederman, N., & Crawford, B. (2004). Developing views of nature of science in an authentic context: an explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education, 88*(4), 610-645.

Shanahan, T., & Shanahan, C. (2012). What is disciplinary literacy and why does it matter? *Topics in Language Disorders,32*(1), 7-18.

Simon, S., Erduran, S., & Osborne, J. (2006). Learning to teach argumentation: Research and development in the science classroom. *International Journal of Science Education, 28*(2/3), 235-260.

Spector, B., Burkett, R. S., & Leard, C. (2007). Mitigating resistance to teaching science through inquiry: Studying self. *Journal of Science Teacher Education, 18*(2), 185-208.

Stiller, J., Hartmann, S., Mathesius, S., Straube, P., Tiemann, R., Nordmeier, V., & Upmeier zu Belzen, A. (2016). Assessing scientific reasoning: A comprehensive evaluation of item features that affect item difficulty. *Assessment & Evaluation in Higher Education, 41*(5), 721-732.

Vazquez-Alonso, A., Garcia-Carmona, A., Manassero-Mas, M. A., & Bennassar-Roig, A. (2013). Science teachers' thinking about the nature of science: A new methodological approach to its assessment. *Research in Science Education, 43*(2), 781-808.

Vygotsky, L.S. (1978). Mind in society: *The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Whitworth, B., Maeng, J., & Bell, R. (2013). Differentiating inquiry. *Science Scope, 37*(2), 10-17.

Wong, S. S., Firestone, J. B., Ronduen, L. G., & Bang, E. (2016). Middle school science and mathematics teachers' conceptions of the nature of science: A one-year study on the effects of explicit and reflective online instruction. *International Journal of Research in Education and Science, 2*(2), 469- 482.

Zeidler, D. L. (1997). The central role of fallacious thinking in science education. *Science Education, 81*, 483-496.

APPENDIX A

CONSENT FORM

Dear Parent/Guardian,

I am finalizing my Doctorate of Education program through the University of South Carolina. My dissertation research is action research. Action research is a method of examining one's own actions and investigating how those actions can influence others to learn. The focus of my dissertation is see how argument driven inquiry impacts a student's ability to develop evidence based arguments and improve content knowledge. I would be very thankful if you would grant your permission for your child to take part in my research.

My research will be looking only at pre and post-test content scores for all of my students and individual work of eight students will be used for data collection. I guarantee confidentiality of information and promise that the name of the school or my colleagues will not be made public. Student names will be replaced by pseudonyms that will make the child unidentifiable.

Participation is easy and will not involve any stress or risks. All students will be taught using argument driven inquiry over the next six weeks. However, if you chose not to have your student participate, rest assured that they will still receive the same instruction as other students. If you wish to be kept informed about the progress of my action research project I can keep you updated. I will be happy to present my work to parents if there is interest.

If you do not want your child's work being used for my study, I would appreciate if you would send me an email stating you do not want your child's work included in my study by the end of this week.

Sincerely,
Mrs. Ross

APPENDIX B

STRUCTURED FORMAL INTERVIEW GUIDE - PRE

Student Name________________________________

Today I'm going to ask you some questions about science, specifically about argumentation in science. Your participation is voluntary and will not affect your grade in this class. Also, you name and all answers you provide will be kept anonymous so answer the questions as honestly as you can.

1. Before the science class you are in now, have you ever had to support a claim with evidence for a class assignment? If yes, explain.
2. Do the terms claim, evidence, and reasoning of evidence make sense to you or is it confusing? Explain.
3. On a scale of 1 to 5, how important is it to provide evidence to support claims? 1 means not important and 5 means very important. Explain
4. On a scale of 1 to 5, how important is it to provide justification for evidence used? 1 means not important and 5 means very important. Explain
5. Is there a difference between data and evidence? Explain
6. Do you feel comfortable reviewing another classmate's idea? Why or why not?
7. What does scientific argumentation mean to you?
8. Do you think scientific argumentation is different than regular conversational arguments? Explain
9. Is there anything else you would like me to know?

STRUCTURED FORMAL INTERVIEW GUIDE - POST

Student Name_______________________________

Today I'm going to ask you some questions about science, specifically about argumentation in science. Your participation is voluntary and will not affect your grade in this class. Also, you name and all answers you provide will be kept anonymous so answer the questions as honestly as you can.

1. How is ADI different than other times you have had to support a claim with evidence for a class assignment?
2. Do you feel confident in your ability to make a claim and support it with evidence and reasoning? How has it changed over the past 6 weeks?
3. On a scale of 1 to 5, how important is it to provide evidence to support claims? 1 means not important and 5 means very important. Explain
4. On a scale of 1 to 5, how important is it to provide justification for evidence used? 1 means not important and 5 means very important. Explain
5. Is there a difference between data and evidence? Explain
6. Do you feel more comfortable reviewing another classmate's idea? Why or why not?
7. What does scientific argumentation mean to you?
8. Do you think scientific argumentation is different than regular conversational arguments? Explain.
9. Do you think using ADI like we did helped you improve your ability in developing evidence-based arguments? Why or why not?

APPENDIX C

PRE AND POST SCIENCE QUESTIONNAIRE

1. I can succeed in science.
   1-------------------------2--------------3--------------4--------------5
   Strongly Disagree----Disagree------Neutral-------Agree-----Strongly Agree

2. I am confident that I understand Science.
   1-------------------------2--------------3--------------4--------------5
   Strongly Disagree----Disagree------Neutral-------Agree-----Strongly Agree

3. Science is hard.
   1-------------------------2--------------3--------------4--------------5
   Strongly Disagree----Disagree------Neutral-------Agree-----Strongly Agree

4. I understand the language of science.
   1-------------------------2--------------3--------------4--------------5
   Strongly Disagree----Disagree------Neutral-------Agree-----Strongly Agree

5. I can interpret data table and graphs in science.
   1-------------------------2--------------3--------------4--------------5
   Strongly Disagree----Disagree------Neutral-------Agree-----Strongly Agree

6. I want to succeed in science class.
   1-------------------------2--------------3--------------4--------------5
   Strongly Disagree----Disagree------Neutral-------Agree-----Strongly Agree

7. I want to understand scientific content.
   1-------------------------2--------------3--------------4--------------5
   Strongly Disagree----Disagree------Neutral-------Agree-----Strongly Agree

8. I can create scientific explanations using evidence.
   1-------------------------2--------------3--------------4--------------5
   Strongly Disagree----Disagree------Neutral-------Agree-----Strongly Agree

9. It is important to create scientific explanations
   1-------------------------2--------------3--------------4--------------5
   Strongly Disagree----Disagree------Neutral-------Agree-----Strongly Agree

10. Scientific argumentation is the same as a regular argument.
1-------------------------2---------------3---------------4---------------5
Strongly Disagree----Disagree------Neutral-------Agree-----Strongly Agree

11. I feel confident in my ability to use evidence to support a claim.
1-------------------------2---------------3---------------4---------------5
Strongly Disagree----Disagree------Neutral-------Agree-----Strongly Agree

12. I can identify effective evidence.
1-------------------------2---------------3---------------4---------------5
Strongly Disagree----Disagree------Neutral-------Agree-----Strongly Agree

13. I have experience in writing arguments using claim, evidence, and reasoning.
1-------------------------2---------------3---------------4---------------5
Strongly Disagree----Disagree------Neutral-------Agree-----Strongly Agree

14. I worry I will hurt another student's feelings if I disagree with them.
1-------------------------2---------------3---------------4---------------5
Strongly Disagree----Disagree------Neutral-------Agree-----Strongly Agree

15. I feel safe sharing my thoughts in science class.
1-------------------------2---------------3---------------4---------------5
Strongly Disagree----Disagree------Neutral-------Agree-----Strongly Agree

16. I feel comfortable sharing my ideas with a small group.
1-------------------------2---------------3---------------4---------------5
Strongly Disagree----Disagree------Neutral-------Agree-----Strongly Agree

17. I feel comfortable receiving feedback from another student about my work.
1-------------------------2---------------3---------------4---------------5
Strongly Disagree----Disagree------Neutral-------Agree-----Strongly Agree

18. I feel comfortable peer editing another student's work.
1-------------------------2---------------3---------------4---------------5
Strongly Disagree----Disagree------Neutral-------Agree-----Strongly Agree

19. I think that science can help change the recognition of current and past wrongs and damages to different groups of people that have been taught or performed by science and scientists.
1-------------------------2---------------3---------------4---------------5
Strongly Disagree----Disagree------Neutral-------Agree-----Strongly Agree

20. I think science can be used to make features, major events, and circumstances of humans better and produce an equitable society.

1--------------------------2---------------3---------------4---------------5

Strongly Disagree----Disagree------Neutral-------Agree-----Strongly Agree

APPENDIX D

GENERATING AN EVIDENCE-BASED ARGUMENT

Directions: Use the information provided to develop a claim, evidence, and reasoning.

1. Examine the following data table:

	Density	**Color**	**Mass**	**Melting Point**
Liquid 1	1.5 g/cm3	No color	56 g	-76 C
Liquid 2	0.917 g/cm3	red	24 g	-42 C
Liquid 3	1.5 g/cm3	No color	33 g	-76 C
Liquid 4	0.68 g/cm3	No color	54 g	24 C

Question: Are any of the liquids in the data table the same substance?

1) In a complete sentence, make a *claim* based on the above data set and based on your knowledge of properties.

2) In complete sentences, use *evidence* from the data table above to support your claim.

3) In complete sentences, give *reasons* to explain why your evidence supports your claim.

4) Write a full paragraph argument where you state your ***claim***, cite your ***evidence*** from the data table, and provide ***reasoning*** to explain why the evidence supports your claim.

2. Gina wants to see if plants really do grow better in sunlight. She uses 3 plants of the same type and size in 3 locations. Plant A is placed on Mr. Conway's countertop in the center of the room, Plant B is placed inside the cabinet, and Plant C was placed near window sill. After 5 days Gina measures the growth of each plant and documents it in the table below.

Gina's Plant Growth Experiment

	Height on Day 1	**Height on Day 5**
Plant A	6cm	7.1cm
Plant B	6cm	6.5cm
Plant C	6cm	7.9 cm

1) In a complete sentence, make a *claim* based on the above data set and based on your knowledge of plants.

2) In complete sentences, use *evidence* from the data table above to support your claim.

3) In complete sentences, give *reasons* to explain why your evidence supports your claim.

4) Write a full paragraph argument where you state your ***claim***, cite your ***evidence*** from the data table, and provide ***reasoning*** to explain why the evidence supports your claim.

APPENDIX E

CONTENT PRE-TEST/POST-TEST

The school district uses Discovery Education Techbook and a sixty-four question pre-test and post-test was created using the item bank. The pre-test can be accessed at https://google.discoveryeducation.com/learn/assessment/272f890e-7844-418d-b32a-202cba8118fc/preview and the post-test can be accessed at https://google.discoveryeducation.com/learn/assessment/e92ad051-f922-4ca2-b431-f63b6939b052/preview . Please note that an account is necessary to access the assessments. Questions used were selection questions based on state determined content standards. Examples of questions from instrument are given below.

38. Earthquakes release a large amount of energy in the Earth's crust. Where does this energy come from?

- **A.** intense radiation from the Sun
- **B.** strong water currents in the ocean
- **C.** the movement of tectonic plates
- **D.** the gravitational attraction of the Moon

---

39. Where are most volcanoes located?

- **A.** in Africa
- **B.** in the middle of tectonic plates
- **C.** along the edges of tectonic plates
- **D.** in the middle of continents

---

40. Many earthquakes occur along the edges of continents that surround the Pacific Ocean. This area is called the Pacific Ring of Fire. Why does this region have so many earthquakes?

- **A.** The water in the Pacific Ocean is very heavy and pushes down on the Earth.
- **B.** Landslides are common along the steep Pacific Ocean coastlines.
- **C.** Plate boundaries occur along the edges of the Pacific Ocean.
- **D.** Strong typhoons are common in the Pacific Ocean.