Spring 5-15-2020

Do students gain scientific inquiry knowledge and practices by participating in a school garden inquiry unit?

Carmen A. Carrion

Georgia State University

ACCEPTANCE

This dissertation, DO STUDENTS GAIN SCIENTIFIC INQUIRY KNOWLEDGE AND PRACTICES BY PARTICIPATINT IN A SCHOOL GARDEN INQUIRY UNIT?, by CARMEN ANGELICA CARRION, was prepared under the direction of the candidate's Dissertation Advisory Committee. It is accepted by the committee members in partial fulfillment of the requirements for the degree, Doctor of Philosophy, in the College of Education & Human Development, Georgia State University.

The Dissertation Advisory Committee and the student's Department Chairperson, as representatives of the faculty, certify that this dissertation has met all standards of excellence and scholarship as determined by the faculty.

____

Renee Schwartz, Ph.D.
Committee Chair

____

Maggie Renken, Ph.D.
Committee Member

____

Patrick Enderle, Ph.D.
Committee Member

____

Natalie King, Ph.D.
Committee Member

____

Audrey Leroux, Ph.D.
Committee Member

____

Date

____

Gertrude Tinker-Sachs, Ph.D.
Chairperson, Department of Middle and Secondary Education

____

Paul A. Alberto, Ph.D.
Dean, College of Education & Human Development

AUTHOR'S STATEMENT

By presenting this dissertation as a partial fulfillment of the requirements for the advanced degree from Georgia State University, I agree that the library of Georgia State University shall make it available for inspection and circulation in accordance with its regulations governing materials of this type. I agree that permission to quote, to copy from, or to publish this dissertation may be granted by the professor under whose direction it was written, by the College of Education's Director of Graduate Studies, or by me. Such quoting, copying, or publishing must be solely for scholarly purposes and will not involve potential financial gain. It is understood that any copying from or publication of this dissertation which involves potential financial gain will not be allowed without my written permission.

Carmen Angelica Carrion

NOTICE TO BORROWERS

All dissertations deposited in the Georgia State University library must be used in accordance with the stipulations prescribed by the author in the preceding statement. The author of this dissertation is:

Carmen Angelica Carrion
Middle and Secondary Education
College of Education
Georgia State University

The director of this dissertation is:

Renee Schwartz PhD
Department of Middle and Secondary Education
College of Education
Georgia State University
Atlanta, GA 30303

CURRICULUM VITAE

Carmen Angelica Carrion

ADDRESS: 855 Piedmont Ave NE, Apt 1J
Atlanta GA, 30308

EDUCATION:

Ph.D.	2019	Georgia State University Teaching and Learning
M.S.	2010	Georgia Institute of Technology, Applied Biology
B.S.	2008	Georgia Institute of Technology, Ecology & Evolution

PROFESSIONAL EXPERIENCE:

2019 - present	Postdoctoral Fellow Georgia Institute of Technology
2018 - 2019	Research Scientist Georgia Institute of Technology
2012 - 2018	Graduate Research Assistant and Instructor on Record Georgia State University

PRESENTATIONS AND PUBLICATIONS:

Carrion, C. C., & LeDoux, J., (2019, October). *Exploring the role of interpersonal interactions on students' levels of cognitive engagement when collaboratively solving a challenging engineering problem.* Paper presentation at the Annual Frontiers in Education (FIE), Cincinnati, OH

Carrion, C., Preksha, K.,Vaswani, D., & LeDoux, J ., *Exploring the role of interpersonal interactions on students' levels of cognitive engagement when collaboratively solving a chal-*

lenging engineering problem. Paper presentation at the Annual Frontiers in Education (FIE), October, 2019, Cincinnati, OH.

Carrion, C., & LeDoux, J., *What range of student motivation and approaches to learning does the Problem-Solving Studio learning environment affect?* Paper presentation at the International Society for the Scholarship of Teaching and Learning (ISSOTL), October, 2019, Atlanta, GA.

Carrion, C., & Schwartz, R., *Do Students Gain Scientific Inquiry Knowledge by Participating in a School Garden Inquiry Unit?* Paper presentation at the European Science Education Research Association (ESERA), August, 2019, Bologna, Italy.

Carrion, C., & LeDoux, J., *Student Perceptions of Interpersonal Skills Intertwined in an Engineering Classroom.* Paper presentation at the American Society of Engineering Education (ASEE), June 2019, Tampa, FL

Carrion, C., & LeDoux, J., *What features of the Problem Solving Studio most impact the students' experience?* NSF poster presentation at the American Society of Engineering Education (ASEE), June 2019, Tampa, FL.

Carrion, C., & Schwartz, R., *School Gardens as a Context to Facilitate Science Practices*. Paper presentation at the National Association for Research and Science Teaching (NARST), March 2019, Baltimore, MD.

Carrion, C., & LeDoux, J., *What do Students Experience in a Problem Solving Studio?* Paper presentation at the Biomedical Engineering Society (BMES), October 2018, Atlanta, GA.

PROFESSIONAL SOCIETIES AND ORGANIZATIONS

2018 -	American Society for Engineering Education
2017 -	National Association for Research & Science Teaching
2017 -	National Science Teaching Association
2016 -	American Education Research Association
2013 -	American Psychological Association

Do students gain scientific inquiry knowledge and practices by participating in a school garden inquiry unit?

by

CARMEN ANGELICA CARRION

Under the Direction of Renee Schwartz PhD

ABSTRACT

Since the turn of the century gardens have been spaces for learning to take place. Gardens allow for a variety of disciplines to be explored from horticulture to art. In the mid nineteen nineties a school garden movement began to grow, in the United States and by the early two thousands several states had implemented a school garden policy. The majority of school gardens focus on academic outcomes (e.g. science, math, or language arts) or health outcomes (e.g. nutrition, well-being, and self-esteem).

Currently, there is limited information about how school gardens can be places for scientific inquiry and practices to develop in students. Furthermore, more in-depth mixed-method research on school gardens and how school gardens can produce learning opportunities for scientific practices to develop need to be conducted. Future research should take a new direction. The scientific practices created by Next Generation Science Standards (NGSS) (LeadStates, 2013) need to be explored further in relation to how exposure to a school garden can affect these practices and knowledge about inquiry learning (Callahan, 2012; Chi, Dorph & Reisman, 2016; Kisiel & Anderson, 2010).

Through this dissertation, school gardens can be viewed as an extension of the traditional classroom. School gardens have the potential to foster learners' abilities to construct real-life associations with science content due to engagement, free exploration, and scientific investigation. This study found school gardens as an out-of-classroom setting where students have the ability to learn and develop their understanding about scientific inquiry and scientific practices. This new avenue may help develop better scientific literacy universally across learners. This research work created curriculum and assessment tools to use in conjunction with an out of classroom setting such as a school garden.

INDEX WORDS: school garden, inquiry, science practices, engineering practices

Do students gain scientific inquiry knowledge and practices by participating in a school garden inquiry unit?

by

Carmen Carrion

A Dissertation

Presented in Partial Fulfillment of Requirements for the

Degree of

Doctor of Philosophy

in

Teaching and Learning

in

Middle and Secondary Education

in the

College of Education

Georgia State University

Atlanta, GA
2019

DEDICATION

This dissertation is dedicated to my parents and brother. They continuously supported me through this journey.

ACKNOWLEDGMENTS

I want to acknowledge and thank my first mentor, Dr. Maggie Renken, who has been with me since day one of my doctoral journey. She always stood by me in the difficult times as well as supporting and pushing forth my passion of nature as a context for teaching. I next want to acknowledge and thank my second mentor, Dr. Renee Schwartz, she understood my research vision and openly took me in. Due to her support and knowledge I have found a discipline where my passion for nature can be intertwined with my scholarly work. And lastly, all the faculty and staff at Gerogia State University who have helped me over the years. I am extremlely appreciative of everyone. You all played a part in my success and I thank you!

Table of Contents

LIST OF TABLES

LIST OF FIGURES

1 CONCEPTUALIZATION OF THE PROBLEM

Introduction

The National Research Council (NRC) has expressed a need for more research on the subject of learning in science domains to help students in K–12 education, the future members of society, become better consumers of science and more scientifically literate (NRC, 2000, 2007, 2012a, 2012b). Scientific literacy can be defined as possessing the knowledge of science and understanding how to apply this knowledge to decisions related to personal and societal situations that contain elements from the domain of science (Lederman, Antink, & Bartos, 2014; Roberts & Bybee, 2014). Currently, school curricula do not create a course of study that shows how science integrates many of the choices an individual makes throughout life. Instead, as pointed out by Roberts in 2007 and then again in 2014, educators and researchers need to create school curricula which illuminate how science penetrates into and interacts with many areas of human accomplishments and life situations, including political, economic, and ethical issues (Roberts & Bybee, 2014).

One avenue that could allow scientific literacy to connect with an individual is from a citizen science perspective or a science-for-all approach (Lederman, Antink, & Bartos, 2014). From this approach, students align their understanding of science with an everyday situation that is relevant to each of them. Different forms of citizen science include but are not limited to: environmental quality, resource use, personal health, and decision-making about socio-scientific issues. By exposing students to a citizen science curriculum, students can begin to see how classroom science relates to their own lives. Students learn how science fits into their own personal and societal perspectives, which facilitates comprehension of more complex issues. Therefore, the goal is to make the classroom a space where students can be taught and become prepared to deal with these socio-scientific issues (Lederman, Antik, & Bartos, 2014). Students need to learn, to dialogue, and to investigate how to solve an issue and make decisions about that issue. This process matches how scientists and researchers make explanations and claims in science itself (Roberts & Bybee, 2014). However, for a classroom space to really emphasize a science-for-all approach and for scientific literacy to develop, the curriculum must relate to personal and societal issues experienced by the students (Lederman, Lederman, & Antik, 2013; Lederman, Antik, & Bartos, 2014; Roberts & Bybee, 2014). By implementing a curriculum that helps students better understand what is happening in their everyday lives, the curriculum exposes students to the necessary skills and knowledge to allow for more informed decision making on political, economic, and ethical issues.

To demonstrate scientific literacy, the individual must have some understanding of the content knowledge, the nature of science (NOS) knowledge, and knowledge of the nature of scientific inquiry (NOSI). Essentially, for an individual to make an informed decision about a scientifically-based issue, the individual must be able to evaluate the claim and evidence related to the scientific knowledge, NOS, and how this knowledge is developed through the process of scientific inquiry (NOSI) (Bell, Lederman, & Abd-El-Khalick, 2000; Eastwood, Sadler, Zeidler, Lewis, Amiri, & Applebaum, 2012; Lederman, Lederman, & Antik, 2013; Sadler, Chambers, & Zeidler, 2004; Zeidler, Walker, Ackett, & Simmons, 2002).

The following sections discuss how NOS and NOSI have confused educators about the "knowing" and "doing" of science and how the process of scientific inquiry has been misinterpreted by both teachers and students. In addition, there is discussion about how the Next Generation Science Standards (NGSS) (Lead States, 2013) practices may lead to knowledge and understanding about the NOS, the NOSI, and the development of scientific literacy when aligned with aspects of the NOSI.

Nature of Science and Nature of Scientific Inquiry

The construct of the nature of scientific knowledge has been studied since the turn of the century, and to this day there is still not a consensus for what exactly it is. However, there is general consensus as to what is relevant and accessible to K-12 learners. For purposes of this study, NOS is defined as the epistemology of science, or the values and beliefs inherent to the development of scientific knowledge (Lederman, 1992). Both NOS and NOSI can be broken down into specific aspects. NOS can be generalized into seven aspects focused around the features of knowledge that make knowledge "scientific", 1) tentativeness, 2) subjectivity, 3) empirically-based, 4) imagination and creativity, 5) socio-cultural embeddedness, 6) distinction between observation and inference, and 7) relationships between scientific theories and laws (Lederman, 1992).

Across three separate domains – philosophy, psychology, and science education – there is agreement that there are underlying structures to the process of inquiry (Osborne, 2014a, 2014b). These structures assist an individual in developing knowledge about science. For this study, the definition of scientific inquiry is framed using Bybee's (2004) explanation of the process. Bybee distilled scientific inquiry into three constructs, all of which integrate with one another. Scientific inquiry is a process consisting of: 1) skills of inquiry, 2) knowledge about scientific inquiry, and 3) pedagogical approaches for teaching science content (Bybee, 2004). This study investigates the first two constructs: skills of inquiry (i.e., what students should be able to perform and do, also known as "practices"), and knowledge about scientific inquiry (i.e., what students should understand and knowledge related to this process) (Bybee, 2014; Schwartz, Lederman, & Crawford, 2004). Scientific inquiry focuses on scientific investigations where the learner is using both inquiry practices and conceptual thinking to solve a problem (Duschl, Schweingruber, & Shouse, 2006; Zimmerman, 2000; 2007). Learners engage in some or all components of scientific inquiry, such as designing experiments, evaluating evidence, and forming or revising theories during their investigation (Kuhn, 2002; Kuhn, Iordanou, Pease, & Wirkala, 2008; Schauble, 1996; Zimmerman, 2007). Understanding the nature of scientific inquiry, including its characteristics, is known as NOSI; it is defined as the methods and processes that assist an individual in the development of scientific knowledge and understanding about the processes of inquiry (Bybee, 2004, 2014; Schwartz, Lederman, & Crawford, 2004). NOSI has been refined into eight general aspects focused on the process of inquiry: 1) questions to guide investigations, 2) multiple methods of scientific investigations, 3) inquiry procedures guided by the question asked, 4) all scientists performing the same procedures may not get the same results, 5) inquiry procedures can influence results, 6) sources of, roles of, and distinctions between scientific data and scientific evidence, 7) research conclusions must be consistent with data collected, and 8) explanations are developed from a combination of collected data and what is already known (Lederman et al, 2014). Understanding the aspects across both NOS and NOSI can ultimately assist an individual in creating scientific knowledge which may then help develop their scientific literacy. The inconsistency in defining what scientific inquiry (SI) is began in the early 1990s. This led many educators to believe that inquiry meant *doing* or *hands-on learning* (Bybee, 2004; Crawford, 2014). By the early 2000s, many researchers in the fields of the learning sciences and science education discerned that inquiry was being used as merely a teaching method rather than a body of knowledge. Teachers and students could perform SI, but they could not explain what kind of knowledge was developed from this process or why certain practices were used. No meaningful understanding was found when teachers and students were performing the practices found in inquiry. By 2014, researchers and educators created both a learning resource, Next Generation Science Standards (NGSS) (Lead States, 2013), and an assessment tool, *Views About Scientific Inquiry (VASI)*, to aid the research targeting learners' comprehension of foundational aspects of scientific practices, i.e., knowledge about the process of scientific inquiry (Lederman et al, 2014).

Next Generation Science Standards

The Next Generation Science Standards (NGSS) were created as a way to aid students and teachers in developing science learning using three dimensions: science and engineering practices, cross-cutting concepts, and disciplinary core ideas (NGSS Lead States, 2013). The idea for this framework is that students should be exposed to different disciplinary core ideas in the context of science and engineering practices. Cross-cutting concepts are the larger ideas that connect and relate different science disciplines; they are embedded within the practices and disciplinary core ideas. All three of these dimensions are integrated. The creators of this framework understood that students cannot fully develop understanding about scientific or engineering ideas without engaging in the practices of inquiry and the discourses from which ideas and theories can be developed and refined (NGSS Lead States, 2013).

NGSS focuses on two defining characteristics: "an emphasis to provide a key tool for understanding or investigating more complex ideas and solving problems" and the idea that "scientific investigation requires not only skills but also knowledge that is specific to each science practice" (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010; NGSS Lead States, 2013). From these characteristics, NGSS attempts to provide a fundamental framework to assist educators and students in developing an understanding about inquiry and the type of knowledge created from this process (NGSS Lead States, 2013). Within the NGSS (Lead States, 2013) framework are eight key practices for learning science: 1) asking questions, 2) developing and using models, 3) planning and carrying out investigations, 4) analyzing and interpreting data, 5) using mathematics and computational thinking, 6) constructing explanations, 7) engaging in argument from evidence, and 8) obtaining, evaluating, and communicating information. These practices are based on problem solving and investigating, which lead to the generation of new scientific knowledge. The NGSS framework captures the complexity and the process of scientific discovery (Quinn, Schweingruber, & Keller, 2012).

Direct involvement with the practices is of the utmost importance because the involvement allows the learner to grasp the wide variety of approaches or methods used during an investigation (Osborne, 2014a, 2014b). Many researchers in science education emphasize the importance of the engagement with these practices (Crawford, 2014; Osborne, 2014). However, this engagement does not only mean the “doing” or “performing” of the practice; engagement also encompasses cognitive engagement. Osborne (2014a, 2014b) explains that the engagement of the practice only has value to the learner if: a) it helps the learner develop a deeper and larger understanding of what current science knowledge is known and the epistemic and procedural constructs that guide the practice of science, b) it is a more effective means of developing science knowledge, and c) it presents a more authentic experience of the endeavor that is science. NGSS supports these science practices because they parallel what scientists and engineers do in the field (NGSS Lead States, 2013). Therefore, students need to engage in the practices to have a more holistic understanding of how these practices help not only to create new scientific knowledge but also how the overall process of scientific inquiry is intertwined with these practices (Osborne, 2014a). By engaging in science practices, the student gains procedural knowledge and could gain epistemic knowledge if explicitly taught the *do* and the *know* (Crawford, 2014; Osborne, 2014a, 2014b). The *do* is how a student applies or performs a practice. The *know* is the knowledge behind why a practice was chosen. Students need the engagement with a practice to understand how the practice fits into the overall process of scientific inquiry. In addition, with the engagement are explicit connections by the instructor and points of reflection by the students during the experience. All of these concepts help students to develop deeper understanding of NOSI.

The NGSS (Lead States, 2013) framework also ties back to aiding individuals in becoming more scientifically literate. By participating in these practices, learners begin to form an understanding of the cross-cutting concepts and disciplinary core ideas of science and engineering that lead to knowledge becoming more meaningful; this scientific knowledge becomes embedded more deeply into their world views (NGSS Lead States, 2013). Students can then relate these worldviews about scientific knowledge with personal and social issues that are relevant to them. Critically thinking about the practices and these larger cultural views can lead to thinking scientifically which aids in the development of scientific literacy. However, questions remain: 1) How do educators and researchers put NOS, NOSI, and NGSS into practice, and how do educators and researchers assess understanding of these concepts? 2) What are youth doing and learning in varying education contexts? Researchers in the Lederman group (2014) recognized one of these gaps and created an instrument that aligns with NGSS practices and NOSI. This instrument, *Views about Scientific Inquiry (VASI)*, investigates how individuals understand scientific inquiry and the practices that occur during scientific inquiry. With this instrument, researchers can now assess how teachers and students understand the NOSI. It is more difficult to answer the second question due to limited research investigating how educational contexts affects NOSI and practices. This second question is explored more thoroughly in a later section.

Next Generation Science Standards and Nature of Scientific Inquiry

All eight aspects of NOSI align with the eight NGSS practices. With these NGSS practices, educators and researchers have another tool to assess students' and teachers' understandings of NOSI. Table 1 below, displays how the NGSS practices align with the aspects of NOSI (Lederman et al, 2014). Note that certain practices may align with several aspects.

Table 1. *NGGS Practices and Aspects of NOSI*

NGSS Practice	Aspects of NOSI
1. Asking questions	Scientific investigations all begin with a question and do not necessarily test a hypothesis.
2. Developing and using models	Explanations are developed from a combination of collected data and what is already known.
3. Planning and carrying out investigations	There is no single set or sequence of steps followed in all investigations.
	Inquiry procedures are guided by the question asked.
4. Analyzing and interpreting data	All scientists performing the same procedure may not get the same results.
	Inquiry procedures can influence results.
5. Using mathematics and computational thinking	Inquiry procedures can influence results.
6. Constructing explanations	All scientists performing the same procedure may not get the same results.
	Research conclusions must be consistent with the data collected.
	Explanations are developed from a combination of collected data and what is already

	known.
7. Engaging in argument from evidence	Scientific data are not the same as scientific evidence. Research conclusions must be consistent with the data collected. Explanations are developed from a combination of collected data and what is already known.
8. Obtaining, evaluating, and communicating information	Explanations are developed from a combination of collected data and what is already known.

It should be understood that even with the creation of a framework and an assessment tool, both NOSI and the associated practices are difficult to assess (Capps & Crawford, 2012; Osborne, 2014b). This difficulty stems from the type of context or content in which NOSI and these practices are performed. Capps and Crawford (2012) explain how researchers and educators should look at how context plays a role in learning in order to develop a true understanding about NOSI and the practices involved. NGSS (Lead States, 2013) echoes this support in the framework by describing that a learner cannot learn or show competence in practices except in the context of specific investigations. A fundamental aspect of NOSI is how the driving research question will guide how the investigation will be performed (Lederman et al, 2014). Nevertheless, when creating a driving question, knowledge about the context and setting influences this fundamental aspect and practice.

The following section discusses situated learning in relation to context and how context sets the stage for both scientific inquiry and the performance of scientific practices. An individual may perform an investigation in one manner depending on the context; just as how context may influence an individual's choice to perform one practice rather than another.

Context, NGSS, and NOSI

By the early 1990s researchers from across psychology and education began to investigate context and learning. Context and setting can affect the overall learning experience for an individual because the context emphasizes what activities and interactions are specific to the chosen context (Brown, Collins, & Duguid, 1989; Lave, 1988; Lave & Wagner, 1991). This can range from an individual participating in laboratory rotations to an individual learning directly from an expert. In both scenarios, the circumstances in which the individual is exposed to provides some guidance and context of what to expect. For example, in the domain of linguistics, a learner can study using a dictionary to increase his vocabulary but this is a solitary interaction; when the same individual practices vocabulary with a native speaker, the learner can learn aspects of how words are used in the native speaker's home culture and how these words are used in everyday interactions. Alternatively, in the field of science, the arrangement of a biology investigation is different than the arrangement of a physics investigation; from the context of the investigation, an individual can tell what type of investigation to conduct. The context primes the student to understand what kinds of questions to ask and how to create an investigation that directly aligns with the context (Lederman, Antink-Meyer, & Bartos, 2012).

This context perspective has become an avenue for science learning and has gained momentum in the field of science education over the last decade. Researchers in this field began to ask, "Does context or setting affect NOSI and students' science practices?" Schwartz and Crawford first began questioning how context affected learners' understanding about NOSI in 2004. They determined that a more authentic context allows for a more transparent use of practices (Schwartz & Crawford, 2004; Schwartz, Lederman, & Crawford, 2004). The authentic experience allowed students to connect the understanding behind the application of a practice. However, they identified an even more interesting revelation in these authentic contexts in that the process of inquiry is nonlinear (Crawford, 2012, 2014; Schwartz & Crawford, 2004; Schwartz, Lederman, & Crawford, 2004). The students in these studies performed scientific inquiry in a manner more similar to that of professionals. Students were not simply going step-by-step, but instead they would return to previous steps to redefine a question or to collect more data; the students' path of inquiry appeared to be more like a spider web rather than a line or circle. By 2014, both Crawford (2014) and Osborne (2014) echo one another in how context and setting create the background for why an investigation will be conducted. These authentic contexts and experiences emphasize the use of scientific inquiry. In addition, science practices are influenced by specific context as well.

The majority of current NOSI and science practices research takes place in formal settings such as laboratories or classrooms. However, beginning in 2012 researchers and educators across various disciplines began to discuss a need for more research in informal or out-of-classroom settings, e.g., museums, aquariums, gardens, science centers (NRC, 2012a; NRC, 2012b). Researchers are now asking: *"Does setting allow students to create more knowledge about the processes of scientific inquiry or does setting allow students to better understand how to apply a science practice?"* More research is needed to investigate the effect of setting on knowledge about NOSI and the application of science practices. This push for more research in out-of-classroom settings is noted in the Framework for K–12 Science Education, Next Generation Science Standards, and the NRC "*Informal Environments Report*" aligns exactly with what science educator researchers have discussed in situated learning research (Bell, Lewesiten, Shouse, & Feder, 2009; NGSS Lead States, 2013; Quinn, Schweingruber, & Keller, 2012; Sacco, Falk, & Bell, 2014). Researchers and educators across disciplines understand that science should not be limited or constrained to inside school classroom settings; students need to make associations with everyday science phenomena (Sacco, Falk, & Bell, 2014; Tal & Dierking, 2014). Instead, learning science in specific contexts or settings may be more beneficial to students than *school science*, i.e., science taught in everyday classrooms. In fact, everyday locations like school gardens, outdoor classrooms, or grassy fields might better facilitate scientific inquiry and understanding the knowledge behind the application of these scientific practices. These out-of-classroom settings allow students to experience science in a more digestible manner because the students are situated in the context, thereby creating knowledge of situations that relate specifically to them; the students are exposed to science in a manner in which they can make associations (Bell, Lewesiten, Shouse, Feder, 2009; Bell, Falk, Hughes, Hunt, Parrish, Ruffin, & Troxel, 2016; Sacco, Falk, & Bell, 2014; Tal & Dierking, 2014).

Currently, there is a gap in the research investigating how knowledge is created through the processes of scientific inquiry in out-of-school settings and the application of this knowledge through scientific practices. This study examined how context such as an out-of-classroom setting, i.e., a school garden, may affect knowledge and practices associated with NOSI when assessed through the combined lens of scientific practices from NGSS and the aspects of NOSI. This dissertation addresses the lack of research investigating the effect of out-of-classroom settings, i.e., school garden, on knowledge created through the processes of scientific inquiry and the application of this knowledge about scientific inquiry through the skill set of scientific practices.

Problem Statement

The overarching goal emphasized across NRC (1996, 2000, 2012), AAAS (1993), and NGSS (Lead States, 2013) is for all individuals in grades K–12 to become more scientifically literate. Completion of this goal should yield individuals who are better consumers of science and better able to understand how the natural world works. Various concepts may guide an individual in developing scientific literacy; for this dissertation, the constructs of NOS, NOSI, and the scientific practices are explicitly explored. These three constructs may facilitate the creation of new knowledge while conducting a scientific endeavor (Bybee, 2004; Roberts, 2007; Roberts & Bybee, 2014). This study was structured to focus on the processes of scientific inquiry (SI). During these processes, an individual may create knowledge. This new knowledge may be understanding the nature of scientific inquiry [NOSI] or applying a specific scientific practice to a particular context. Both understanding and creating knowledge about the processes of scientific inquiry and how the application of different practices can be used in NOSI can help an individual to develop scientific literacy.

Research conducted over the last two decades still depicts that there is little empirical evidence to explain how SI is best learned by students (Crawford, 2004, 2014; Schwartz, Lederman, & Crawford, 2004; Osbourne, 2014a, 2014b). Furthermore, the notion of context and setting as an avenue to help develop SI is an area in the literature that needs to be explored further. Consequently, there is little to no empirical evidence on context, specifically on out-of-classroom settings, and how these settings facilitate the development of knowledge about the process of scientific inquiry (NOSI) and the application of scientific practices (NGSS practices).

This study helps to close this gap by investigating how an experience in an out-of-classroom setting in the form of a school garden intervention can help students develop knowledge and understanding about the NOSI and to how to perform science practices in specific settings. From this intervention, students may develop a better understanding of why scientists and engineers use scientific inquiry to problem solve and how different scientific practices are applied to specific problems.

In the current field of out-of-classroom setting research, researchers and educators have not found an instructional method or curriculum that best develops a learner's knowledge about the process of SI and an instructional method or curriculum that teaches students how context can influence how specific scientific practices are applied. A new avenue of research needs to investigate the process of SI and the application of practices in out-of-classroom settings.

In addition, it should be noted that the majority of studies discussing SI are conducted in formal settings. A formal setting is a space in which a learner is typically in a controlled environment (Hofstein & Rosenfeld, 1996). A controlled environment can be a laboratory or a traditional classroom. However, everyday science phenomena do not occur in controlled settings; therefore, these formal settings do not always provide students with an authentic experience with science phenomena (Adams, Gupta, DeFelice, 2012; Montgomery, 2008). Instead, an out-of-classroom setting may be the missing link to help students better understand the processes of scientific inquiry.

Out-of-classroom settings, e.g., a school garden, museum, or aquarium, can be viewed as the link between traditional classroom science and authentic, "real world" science (Rennie, 2007, 2014). These out-of-classroom settings have the potential to foster learners' ability to construct real life associations with science content through engagement, free exploration, and the process of SI (Sacco, Falk, & Bell, 2014). The current gap in out-of-classroom setting research does not inform scientists or educators about the kind of curricula, instructions, or assessments to use when teaching in this type of setting. In particular, current research on SI does not clarify whether students are gaining knowledge about the processes of scientific inquiry due to the actual setting or due to the instruction. Furthermore, literature on scientific practices does not fully explore how setting may affect how a student understands and applies a specific science practice. The goal of this research is to investigate the process of SI in out-of-classroom settings and the application of science practices in these environments to find new avenues to help develop scientific literacy in K–12 learners. For this study, the specific questions that will guide this research are**:**

(1) How does participation in the school garden inquiry unit affect students' understanding of the nature of scientific inquiry?

(2) How does participation in the school garden inquiry unit foster students' scientific practices?

Future work may need to focus on curricula and assessment tools of out-of-classroom settings that both educators and researchers may utilize to investigate if knowledge about the process of scientific inquiry is occurring in the out-of-classroom settings and how science practices are developing and applied in specific out-of-classroom settings.

Significance

Currently, there is a dearth of research on student experiences in out-of-classroom settings, i.e., school gardens, and how this novel setting can facilitate more knowledge and understanding about the processes of scientific inquiry. In addition, researchers need to explore how these settings, i.e., school gardens, affect the development and application of science practices. It is of utmost importance to understand whether out-of-classroom settings can be a new avenue to promote more understanding and knowledge about SI and how specific science practices are performed due to specific settings, see Figure 1 below.

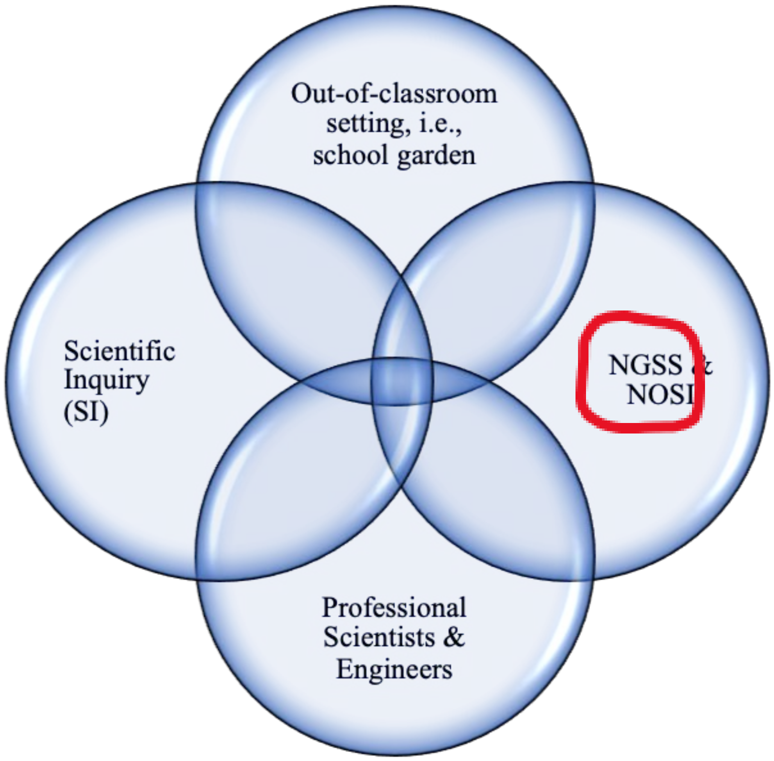


Figure 1. *Venn diagram representing the four constructs and how each have a role in the intervention. The intersect of these constructs is circled in red.*

Figure 1 visually depicts the interplay between the four major constructs in this dissertation: scientific inquiry, NGSS/NOSI, out-of-classroom setting (school-garden), and skills professional scientists and engineers perform throughout their career. These constructs will be explored further in later chapters.

Consequently, there is limited information about how an out-of-classroom settings can be a place for students to develop knowledge about NOSI and how students perform specific science practices due to setting. There is even less information about using the context of a school garden as an avenue to teach these two concepts. This lack of information provides a crucial opportunity to research out-of-classroom settings and how these settings produce learning opportunities for NOSI. In addition, the scientific practices within NGSS (Lead States, 2013) need to be explored further in relation to how exposure to out-of-classroom settings can foster these practic-es and serve as a means for developing understanding about NOSI (Callahan, 2012; Chi, Dorph & Reisman, 2016; Kisiel & Anderson, 2010).

2 REVIEW OF THE LITERATURE

The following sections in this chapter will set the stage for understanding the various constructs that play a role in this dissertation. The constructs of the nature of science (NOS), the nature of scientific inquiry (NOSI), and how setting may influence learning the process of scientific inquiry (SI) and practices will be explored.

Nature of Science

The construct of the NOS knowledge has been studied since the turn of the century, and to this day there is still not a unified consensus over what exactly NOS is. For purposes of this study, NOS is defined as the epistemology of science, or the values and beliefs inherent to the development of scientific knowledge (Lederman, 1992). Due to the lack of consensus over what exactly constitutes NOS, this dissertation's foundation is built using the Lederman (1992) construct of seven aspects of NOS, see Table 2 below. These aspects are generalized because they can be seen across all disciplines in science. These aspects are characteristics for scientific enterprise (Lederman, 1992; Lederman & Lederman, 2014; Lederman, Lederman, & Antik, 2014).

Table 2. *NOS Aspects and Descriptions*

Aspect	Description
Tentativeness	Scientific is subject to change due to new observations and technology. Also, reinterpretations of existing data can lead to change.
Empirically-based	Scientific knowledge is based on and/or derived from observations of the natural world.
Subjectivity	Current scientific theories and laws influence Science. Also, personal subjectivity due to the personal values, agenda, and prior experiences of scientists.
Imagination/creativity	Scientific knowledge is created from human imagination. This involves the invention of explanations as well as how data is interpret-

	ed.
Sociocultural embeddedness	Science is a human endeavor and is influenced by society and culture. The values of the culture determine what and how science is conducted, interpreted, accepted, and utilized.
Distinction between observation and inference	Science is based on both observations and inferences. Observations are collected through the human sense or extensions of those senses. Inferences are interpretations of these observations. The perspective of the scientist and current culture guide both observation and inferences.
Relationships between scientific theories and laws.	Theories and laws are both different types of scientific knowledge. Laws describe relationships observed or perceived from phenomena in nature. Theories are inferred explanations for natural phenomena. A theory or law may be created with the accumulation of substantial supporting evidence and acceptance in the scientific community. Furthermore, laws and theories do not progress from one another, there is no hierarchy, because laws and theories are fundamentally different and function differently from one another.

(Schwartz, Lederman, & Crawford, 2004)

These seven aspects work with one another and cannot be teased apart (Schwartz, Lederman, & Crawford, 2004). Each of these aspects is always influenced by culture and society as well as the theoretical framework and personal subjectivity of the scientist or researcher who is conducting the work.

Since the early 1990s, researchers have realized that many teachers and their students lack adequate understanding of NOS (Lederman & Lederman, 2014). One reason for this may be that teachers and students are not given the learning opportunities or experiences to conduct scientific investigations (Lederman & Lederman, 2014). The American Association for the Advancement of Science [AAAS] (1993) and the National Research Council [NRC] (1996, 2000,

2002) have recommended that K-12 science education begin with learning about the *nature* of science through the *processes* of science. Therefore, NOS has been conflated with science processes when science processes are more in line with SI (Lederman, Antink, & Bartos, 2014). Recall that NOS is the values and beliefs inherent to the development of scientific knowledge, not the processes conducted during the endeavor of science (Lederman, 1992). In the early 2000s, researchers in science education and the learning sciences began to explore how inquiry could be used as a tool to teach about science as well as its own body of knowledge. The NOS research began a new vein of work specifically about inquiry and how inquiry is an avenue for learning about the large overarching concepts that make up the nature of science.

Both NOS and inquiry interact and integrate with one another. Scientific processes should be understood as the activities or tasks related to collecting or analyzing data, e.g., observing. These science processes align with tasks and activities which may be demonstrated through the process of inquiry. Therefore, the recommendation to conduct more NOS investigations has actually caused confusion about ways to teach NOS. The use of inquiry to aid in teaching students about the seven aspects of NOS has caused many educators to view "inquiry" as only a teaching method rather than both a teaching method and an educational outcome (Crawford, 2014).

Scientific Inquiry

The use of inquiry with scientific investigations was first brought to the forefront of education research by the NRC (1996). The NRC wants K-12 education to instill in its students that the process of inquiry is how scientists understand and explain the natural world. In addition, the NRC wants educators to acknowledge the differences and variety of approaches among the different disciplines within the domain of science (Bybee, 2004).

Inquiry is a process that involves skills or practices and the understanding of knowledge about the process of investigating. Inquiry is a method for an individual to learn what is unfamiliar by relating it to what is already familiar (Bybee, 2004). There is disagreement over what is defined as inquiry, and this disagreement may be why inquiry is not necessarily seen in many current classrooms (Crawford, 2004, 2007, 2014). Inquiry as a teaching strategy should capture the spirit of scientific investigations and the development of knowledge from the natural world. Inquiry is a method of engaging students in designing and carrying out investigations. The student learns science subject matter by engaging in these investigations (Crawford, 2014). Students should not be passively listening or taking notes while the teacher is performing the investigation. Instead students should be actively trying to connect the material with their prior knowledge as well as trying the investigations themselves. In addition, inquiry units cannot be over-structured and guided by step-by-step instructions. Teaching inquiry, according to Bybee (2004), centers on the learner’s mental activity: aligning prior knowledge with new knowledge, creating connections between the investigation and phenomena, and deciding when to conduct specific practices. These mental activities become *scientific inquiry* in orientation because the learner is producing questions or conducting investigations about natural phenomena. The goal of scientific inquiry is to develop explanations connected to current scientific knowledge; it has elements of justification, and it communicates new knowledge to peers.

Due to the desired change and reform suggested by the NRC (1996, 1998, 2000) and AAAS (1993), inquiry began to be implemented in classrooms across the country from the early 1990s to today’s classrooms. During the first decade, the term “inquiry” was synonymous with performing skills or doing science. The research group of Krajcik, Blumenfeld, Marx, Bass, Fredricks, and Soloway (1998) demonstrated with a nine-month case study how eight urban middle school students were able to learn concepts from inquiry through investigations such as asking questions and designing investigations in their science classrooms. However, the students did not understand how they were gaining knowledge through the creation and implementation of their investigations. In addition, this study exposed how science teachers themselves needed help in understanding how to implement inquiry activities as well as a deeper understanding behind the process of inquiry. The students in this study needed more scaffolding to create meaning from their investigations but the teachers did not have the tools or knowledge to assist these eight students. In a similar methodological approach, Barbara Crawford (2000) observed and centered a study on one experienced high school biology teacher. He developed an “inquiry-based environment” for his students as well as intertwining inquiry-based instruction with his classroom practices. Crawford found that student learning was highly correlated with the teacher’s role in the classroom. Analysis of the nine lessons found that “collaborative inquiry” was being used; students were the driving force behind their investigations. Crawford observed that the teacher took a more interactive role to help students create connections between the ecology content and the inquiry-based lessons. However, unlike in the previous study by Krajcik et al (1998), the teacher in this Biology class was experienced with the process of inquiry and he felt comfortable explaining the process to his students in the form of nine different lessons. To further explore if inquiry can be taught through participating in inquiry-oriented projects and investigations, Bell, Blair, Crawford, and Lederman, (2003) investigated an apprenticeship program between professional scientists (mentors) and high schoolers (mentees). Mentors claimed students would understand the nature of inquiry by engaging in lab work. However, the majority of students did not develop a deeper understand about the process of inquiry. Instead, this study revealed how mentors made assumptions about their students’ learning and comprehension without even discussing the concepts with the mentees. Researchers in this study realized that explicit connections were needed for the mentees between their field or laboratory work and how it related to the larger aspects of inquiry. In addition, mentors needed to be more overt when assisting a mentee in overcoming a misconception (Bell, Blair, Crawford, & Lederman, 2003). As discussed in this article and the two previous articles, students were experiencing more inquiry in the classroom and were participating in inquiry tasks but still were not always learning from these inquiry experiences.

By the mid-2000s some change could be identified in inquiry-based science, predominately in how curriculum and activities aligned with standards regarding the process of inquiry. In 2004, the Marx et al (group) conducted a three-year longitudinal study, with Detroit city schools. Urban middle-schoolers and teachers were exposed to a new inquiry project curriculum using learning technologies software (Marx, Blumenfeld, Krajcik, Fishman, Soloway, Geier, & Tal, 2004). Teachers in this study received professional guidance to develop understanding about the inquiry curriculum and implementation. Findings did demonstrate that student learning could occur with the use of inquiry-based curriculum but the findings also highlighted the fact that teachers were the largest contributing factor in hindering student learning about inquiry. Researchers found that the more consistent a teacher was in attending professional development and working with the curriculum, the easier it was for the teacher to instruct and use the inquiry-based activities which led to higher learning outcomes for students in classes with experienced teachers (Marx, Blumenfeld, Krajcik, Fishman, Soloway, Geier, & Tal, 2004).

By 2010, the majority of science curriculum in the middle grades aligned with national or state standards. Classroom activities and tasks also aligned with standards over the process of inquiry (Trundle, Atwood, Chrsitopher, & Sackes, 2009; Wolf & Fraser, 2007). Notably, numerous inquiry studies investigating classroom inquiry have very similar findings about student learning. Students were gaining some knowledge by performing inquiry; from classrooms to laboratories students were performing inquiry in various environments. Across these studies similar implications have been noted; students were not reflecting on why they were performing these investigations and teachers were not facilitating students in making connections about knowledge made by using the process of inquiry (Maulucci, Brown, Grey, & Sullivan, 2014; Trundle, Atwood, Christopher, & Sackes, 2009; Wolf & Fraser, 2007; Yager & Akcay 2010).

In reality, what researchers found is that the inquiry-oriented curriculum is not sufficient for student learning about the process of inquiry. Inquiry research revealed how the teacher's role is a crucial piece in understanding the inquiry process. Teachers are a driving factor in how students come to comprehend the process of inquiry (Yager & Akcay, 2010). Teachers must facilitate discussions about why professionals perform inquiry and how inquiry applies to the domains of science and engineering. Instead, some teachers are enabling students by only having students perform inquiry skills. These teachers should also be asking students what knowledge they are gaining by performing inquiry. In this new vein of research, results demonstrate that inquiry-oriented activities are not of most value to help students understand how this process creates new knowledge (Maulucci, Brown, Grey, & Sullivan, 2014; Trundle, Atwood, Christopher, & Sackes, 2009; Wolf & Fraser, 2007; Yager & Akcay 2010). The driving factor in how students comprehend the process of inquiry is the teacher (Yager & Akcay, 2010). Teachers must facilitate discussions. However, some teachers hinder students by only having students perform inquiry skills. Instead, these teachers should also ask students what knowledge they gain by performing inquiry and the overall inquiry experience. From these inquiry studies, the results indicate that teachers were not explicitly making connections for students discussing how inquiry activities foster the creation of new scientific knowledge. In addition, students were not reflecting on how inquiry from both a curriculum and instructional perspective related to how they associated with everyday science phenomena and problem solving.

As discussed with these various studies about inquiry in the classroom, for almost two decades inquiry was simply viewed as the *doing* of science. In reality, inquiry does not translate to *hands-on* or *discovery learning*. Students cannot simply only display the process; they must demonstrate understanding and knowledge about the process. A common misconception about inquiry is that only certain disciplines can be grounded in inquiry when, in reality, inquiry is not situated in a subject matter. The overall process of inquiry is consistent among all disciplines of science (Crawford, 2004, 2007, 2014).

As more teachers began using inquiry to teach science and NOS, researchers began to realize that by *doing* inquiry, students were not assisted in developing an understanding of or knowledge about why the process of inquiry is performed. Consequently, students could not learn this new concept if teachers were also confused and unsure how to teach the concept. Lederman (1998) first noticed this in his yearlong case study in which five biology teachers were followed. The findings from the study demonstrated that teacher experience, intention, goals, and understanding of NOS influenced their classroom practice. Students did not learn from teacher modeling or demonstrations. Lederman noted how teachers needed to address NOS aspects with explicit instruction and connection to an activity for students to grasp a more meaningful understanding. Even though this article focused on NOS, it is an example of the importance of the teacher as the liaison between new material and the tasks being performed by students. Four years later after the Lederman (1998) biology teacher paper, he teamed up with another researcher, Schwartz, and continued work investigating teachers, NOS, and inquiry. They found that the teacher's knowledge over a content area along with the teacher's intention behind learning a concept highly influenced how the teacher would teach NOS and whether students would learn the NOS material (Schwartz & Lederman, 2002). When teachers understood the aspects of NOS and practiced implementing activities, the students of these teachers would actually learn more about NOS than teachers who did not feel confident and were new to the material. In addition, Schwartz and Lederman (2002) found that it was difficult for teachers to teach NOS if the teachers themselves held naive views. Teachers must want to understand NOS and inquiry for it to be seen in their classroom instruction. Teacher knowledge and teacher intentions are key components to learning these abstract aspects.

Abed-el-khalick et al (2003), created a special article describing the current issues at the time concerning inquiry in science education across six different countries on three continents. These researchers wanted to illuminate the similar issues around the term "inquiry." They explained how inquiry cannot be taught directly. Instead, inquiry is learned through experience and interaction. They noted how teachers need more pedagogical experiences in using inquiry during classroom practice. The major issue identified across the countries was that teachers were making assumptions about their students' learning. They were assuming that because their students have been exposed and have gone through the motions of inquiry that their students had implicitly learned what inquiry is. Overall, this international article pointed out how more research is needed about students and the process of inquiry, as well as about teachers and how they teach inquiry to their students.

Many of the international authors met together less than a year later to write a book about scientific inquiry and NOS (Flick & Lederman, 2004). This was one of the first books published that teased apart what science educators and learning scientists were observing in science classrooms around the early 2000s. Throughout the book, the authors described how teachers in the early 2000s were not equipped to teach inquiry. Teachers did not necessarily see the connections between NOS and inquiry. Researchers of this book expressed how teachers needed more scholarship in the areas of inquiry. This scholarship may help some teachers dispel some of their misconceptions about NOS and inquiry. Teachers do have the ability to create more inquiry-oriented classrooms but teachers need additional guidance. Lastly, various chapters noted how teachers needed to create complex interactions with their students. It is through these interactions that more learning opportunities may occur.

The studies described to this point helped Schwartz, Lederman, Khishfe, Lederman, Matthews, and Liu, (2002) further their NOS and inquiry research to include an instructional approach. These researchers were interested in how explicit instruction relevant to NOS and inquiry can improve a student's conceptions about NOS or inquiry. By explicit and reflective instrumentation, this group did not mean direct instruction through declarative statements about NOS and inquiry (Schwartz et al, 2002). Instead, explicit instrumentation points to the learning experience where aspects of NOS and inquiry are purposefully taught in tandem with science content through inquiry-based experiences (activities, investigations, historical stories, etc.) where the teacher is intentionally drawing the learner's attention to relevant NOS and inquiry aspects through class discussions and reflective questioning. This novel instructional approach between explicit and reflective practice was implemented in 2004 with fifty-two teachers through the professional development program, Project ICAN (Inquiry, Context, and Nature of Science). This project was created to promote teachers' and students' knowledge of nature of science and scientific inquiry (Lederman & Lederman, 2004). The findings from this study were remarkable; students exhibited significantly improved understandings of those aspects of NOS and inquiry addressed explicitly by their teachers. The findings supported the hypothesis that NOS and inquiry are learned best when given explicit instructional attention, as opposed to the persistent assumption that students learn NOS and inquiry implicitly as they do science (Lederman & Lederman, 2004).

However, by 2010 researchers Harris and Rooks were reiterating what various authors had already described as challenges for teaching NOS and inquiry to students. The greatest factor was always the teachers and their classroom practices. Harris and Rooks (2010) commented on how teachers needed preparation about what inquiry is, what an inquiry-based classroom looks like, and what inquiry-based instruction look like in practice. Just as students need practice and exposure with NOS and inquiry, so do teachers.

By the late 2000s, even if policy makers wanted inquiry to be implemented in classrooms, the research at the time demonstrated that teacher understanding of NOS and how it related to inquiry did not translate into classroom practice. Due to this realization, the research group of Schwartz, Lederman, and Lederman (2002) began to investigate how individuals, both teachers and students, understood the process of inquiry. This area of investigation became known as the Nature of Scientific Inquiry (NOSI). The difference between NOS and NOSI is that NOS is more intertwined in the epistemological underpinnings of why activities were being done in science (Lederman, Antink, & Bartos, 2014) whereas NOSI was more intertwined with the actual practices involved in the process of scientific inquiry, how scientific knowledge can be created from this process, and the use of these practices (Lederman, Antink, & Bartos, 2014). Nature of scientific inquiry is related to science processes but goes beyond just process skills such as observing, inferring, predicting, measuring, questioning, interpreting, and analyzing data. NOSI includes these skills but also refers to combining process skills with scientific knowledge and critical thinking to aid in the development of new scientific knowledge (Lederman, Antink, & Bartos, 2014). The AAAS (1993, 2014) and NRC (1996, 2000, 2012) want students to develop scientific questions and design investigations that may answer these questions. With the proper understanding and use of SI, the process of inquiry will assist students in their scientific endeavors and creation of knowledge about SI.

Nature of Scientific Inquiry

Scientific inquiry can be differentiated into three forms: descriptive, correlational, and experimental. There is a perception that there is only one scientific method to use, classical experimental design (Crawford, 2014; Lederman, Antink, & Bartos, 2014). Classical experimental design is tied to the scientific method, which is a linear method to perform experiments. However, there is not only one course of action to conduct an investigation; this "scientific method" does not exist. This is the narrow and distorted view that much of K-12 education understands as scientific inquiry (Crawford, 2007, 2014).

Scientific inquiry can be divided into three separate constructs: practices of inquiry (what students are able to do), what students know about inquiry (knowledge and understanding), and the pedagogy of how scientific inquiry should be taught (Bybee, 2004; Crawford, 2014). Many educators believe that scientific concepts can be learned simply by doing; they view inquiry as a teaching approach to be used to develop scientific knowledge rather than a content area, and an understanding that scientific inquiry is a process conducted by those seeking a science investigation (Crawford, 2014; Lederman, Antik, & Bartos, 2014). However, students cannot just perform the practices used through scientific inquiry; they must also explain how the practices aid in developing scientific knowledge (Schwartz & Crawford, 2004).

Over the last two decades, researchers still have not established consistent interventions or programs that can help teachers and students understand SI. More empirical studies are needed to identify components of effective curricula and features of programs (Flick, 2004). One leading research group that investigates how individuals understand and view scientific inquiry is the Lederman, Lederman, Bartos, Bartels, Antink-Meyer, and Schwartz (2014) group. This research group created a framework about the main aspects found in Nature of Scientific Inquiry (NOSI), see Table 3 below.

Table 3. *NOSI Aspects and Descriptions*

Aspects	Descriptions
Scientific investigations all begin with a question and do not necessarily test a hypothesis	Scientific investigations involve asking and answering a question and comparing the answer with what scientists already know about the world. But not all investigations have a formally stated hypothesis.
There is no single set or sequence of steps followed in all investigations (no scientific method)	There is a variety of research methodologies across and within the domains of science. Methods are guided by the “question being answered”.
Inquiry procedures are guided by the question asked	There is an alignment between the research question and the method. The overall question governs the methodological approach to be used.
All scientists performing the same procedures may not get the same results	Scientists come from different theoretical backgrounds and may not interpret data the same. Scientists may ask similar questions, follow similar procedures, and still come up with different conclusions.
Inquiry procedures can influence results	The operationalization of variables, the methods of data collection, and how variables are measured and analyzed all influence the conclusions reached by the researcher.
Research conclusions must be consistent with	Each research conclusion must be supported

the data collected	by evidence from the data collected. The strength of a scientist's claim is a function of the evidence that supports it. This claim is further supported when the research methods and research question also align with the data collected.
Scientific data are not the same as scientific evidence	Data and evidence are different and serve different purposes in a scientific investigation. Data are observations collected by scientists during the process of an investigation. Evidence is a product of how the data was interpreted and analyzed by the scientist to answer the research question. This difference is important because there is a potential source of bias.
Explanations are developed from a combination of collected data and what is already known	Scientists make sense of observations by creating explanations. These explanations are guided by current knowledge and conclusions as well as empirical data collected and by findings from previous investigations and currently accepted scientific knowledge.

(Lederman et al, 2014)

These eight aspects are interrelated and together explain the construct of NOSI. The eight aspects can be separated to allow for easier understanding. But, just as with NOS, the eight aspects of NOSI overlap and work with one another. Therefore, if the aspects are taught separately it needs to be emphasized through instruction that in reality the eight aspects are all intertwined with one another (Lederman, et al 2014).

Nevertheless, as previously discussed, by 2010 the majority of teachers and their students were still confused about what inquiry is and what is gained from participating in the process of inquiry. In the vein of the Lederman group, these researchers began NOSI research with teachers, then teacher practices, then activities which the teacher implements, and finally student outcomes. Over numerous studies, the researchers were able to identify three critical concepts when teaching NOSI and NOS: explicit direction, inquiry-oriented activities, and student reflections.

An early study that was able to demonstrate the use of two critical concepts was undertaken by Khishfe and Abd-El-Khalick (2002) in which they worked with two sixth-grade classes. One group was the treatment class, where researchers taught NOS through explicit instruction and inquiry-oriented activities. The second group, the comparison class, was taught NOS but only through the inquiry-oriented activities. These researchers found that activities alone were not enough to help students fully comprehend what NOS and inquiry are. The treatment class with the explicit connections was to learn not only aspects of NOS but also knowledge behind the process of inquiry and why inquiry is used to learn about NOS. This early study was a foundational piece in emphasizing the need of explicit/reflective approaches when learning about NOS and inquiry.

In a more recent inquiry study, Bartos and Lederman (2014) investigated teacher misconceptions about inquiry, and how teachers implement inquiry into practice. Researchers in this study implemented a tool for reflection over knowledge structure for NOS and SI. With the use of this tool, teachers explicitly reflected on the structure of subject matter. As in the Schwartz and Lederman (2002) study, teachers may hold informed views about NOS and SI, but when observed, the teachers could not put NOS and SI into classroom practice. The teachers needed to be explicit in their classroom practice as well as designate time for reflection from both a teacher and a student perspective. Both the teachers and the students were able to learn about NOS aspects. However, the majority of teachers and students could not explain the knowledge gained from the process of inquiry or why inquiry was used to learn about NOS.

A more recent study investigating SI and NOSI was completed by Strippel and Sommer (2015). They focused predominately on chemistry teachers and whether their laboratory practices align with SI and aspects of NOSI. They found that the majority of teachers do understand and claim valuing SI. However, as in the Bartos and Lederman (2014) study when teachers were asked to put their inquiry knowledge into classroom practice (or in this case, laboratory practice), teachers had difficulty with implementing the NOSI aspects. Teachers found it difficult to teach NOSI through inquiry. Furthermore, the researchers found that NOSI was not a primary goal of teaching for these teachers. This again supports what Lederman (1998) and Schwartz and Lederman (2002) found in their teacher studies; for NOS, NOSI, and inquiry to be internalized by the student, the teacher must first value and understand those concepts.

Other NOSI could be discussed, but the majority of these studies have kept to the Lederman (Group) ideas. This group suggests incorporating the three concepts of explicit direction, inquiry-oriented activities, and student reflection when teaching students about NOS, SI, and NOSI. However, this mode of explicitness and reflective teaching has not become prevalent in all inquiry studies. Instead, the majority of studies investigating inquiry from the perspective of instruction and inquiry-oriented activities are more often than not related to the Lederman research group.

One way that educators and researchers have tried to relate and to explain the aspects of NOSI is through the skills or practices that are developed during the process of inquiry (Crawford, 2014). Consequently, for students to gain knowledge and understanding about the nature of scientific inquiry, they must engage in the practices or the *doing* of inquiry. However, in addition to the action of a practice, they must have explicit instruction, connecting the practices to the aspects of NOSI (Capps & Crawford, 2012; Schwartz, Lederman, & Crawford, 2004). Furthermore, students must reflect on the practices they are performing and how that practice leads to the development of scientific knowledge. During points of reflection, students should be engaged in the discussion of why scientific investigations are designed in certain ways (Lederman, Lederman, & Antik, 2013). NOSI needs to be addressed explicitly by the instructor when being taught, and students should have time to reflect and understand how these aspects relate to the NOSI, the students themselves, and the investigation they are conducting (Crawford, 2014; Osborne, 2014).

However, as noted earlier, there is not one simple definition describing what scientific inquiry is. Because of this inconsistency, many teachers and students do not know or understand what SI is or the practices used throughout the process. In 2012, researchers and educators released, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas*. This framework was the groundwork for the creation of Next Generation Science Standards (NGSS) (Lead States, 2013). The NGSS aligns the aspects of NOSI with the practices performed during scientific inquiry. Teachers and students now have a resource to help provide some clarity when learning about SI and scientific practices.

Practices

Recall from the introduction that the Next Generation Science Standards created a framework for learning science that includes eight key practices: 1) asking questions, 2) developing and using models, 3) planning and carrying out investigations, 4) analyzing and interpreting data, 5) using mathematics and computational thinking, 6) constructing explanations, 7) engaging in argument from evidence, and 8) obtaining, evaluating, and communicating information (NGSS Lead State, 2013). These practices define how an individual may engage in the process of SI. This process of inquiry and use of practices prepares an individual to solve problems and investigate questions which may lead to new scientific knowledge (Quinn, Schweingruber, & Keller, 2012). However, engagement with the practices and “doing” inquiry does not translate to learning or the creation of knowledge. The understanding and knowledge behind each practice is necessary to fully grasp the construct of SI (Bybee, 2014).

The eight scientific practices represent what students are expected to do and to display; they are not a teaching method or curriculum (Bybee, 2014). The practices created by NGSS align with the eight aspects of the nature of science inquiry (NGSS Lead States, 2013). This is intended to aid educators in understanding the process of inquiry and how knowledge and understanding of this process is created while engaging in these practices and reflecting on the overall process (Bybee, 2014). The aforementioned point of reflection is critical in creating knowledge about scientific inquiry. Making connections to current scientific knowledge is required to create knowledge about the process of scientific inquiry (Osborn, 2014a).

Context and Setting

In the early 1990s, more science educators were advocating for different types of learning opportunities for students (Gaskell, 1992). Teachers were noticing that students within the science classroom appeared bored and uninterested in the science concepts which they were being taught (Gaskell, 1992). In contrast, teachers would hear about students' experiences at out-of-school locations such as a museum, science center, or botanical garden and students would express enjoyment and excitement about being exposed to a new science concept (Braun & Reiss, 2006).

Setting and context are important for learning because both can facilitate the understanding of new information (Chi, Dorph & Reisman, 2016). Setting and context can be a driving force to prime a student and to help foreshadow what the student will be exposed to in a course of study (Chi, Dorph & Reisman, 2016). For example, if a student steps into a chemistry laboratory, this setting could prime the student to think about elements, experiments, and chemistry formulas. If a student attends an aquarium and enters a river exhibit, this setting could prime the student to think about life science, habitats, and ecosystems. Setting and context should be viewed as an instructional tool not just as a place or location where learners are housed. If students are being exposed to the same science concepts, what is it about this out-of-classroom experience that facilitates students to want to learn and to be more engaged with the subject matter? The following section describes how context and setting are the areas where more empirical studies focused on NOSI and practices should be conducted to better understand how students develop inquiry knowledge and practice skills.

Authentic Science and School Science

Students have shown a disinterest in their science classes as they mature (Braun & Reiss, 2006). In the United States, the 6-12 curriculum is distributed between all disciplines of science. Due to this separation, the content and material taught in school science becomes more difficult for students to relate to as they rise through school (Braun & Reiss, 2006; Gaskell, 1992). Furthermore, because school science is compartmentalized, students may not even learn how the material being taught relates to their daily lives. What occurs is that students cannot apply the school science they have learned to the real world. School science relies heavily on "cook book" laboratories and experiments occurring in a linear fashion (Gaskell, 1992). Students are not thinking as critically as they could in their school science classrooms because everything is being presented to them (Chinn & Malhotra, 2002). Instead, science in the *real world* is complex, less structured, not compartmentalized and extremely integrated (Braun & Reiss, 2006). Much of school science teaching is currently outdated and restricted. Students are not given the exposure or experience to view how the community of science actually works. Many researchers have argued that the best mode for students to learn science when compared to school science is through an authentic science experience (Braun & Reiss, 2006; Chinn & Malhotra, 2002). Authentic science is comprised of activities that provide more naturalistic experience and that are more aligned with what current scientists and engineers do in the *real world* (Chinn & Malhotra, 2002). The authentic science experience allows for more open-ended tasks and less structured problems for student engagement. The more *authentic* the experience, the better; students begin to realize in more authentic contexts that problems are often ill-defined and that the needed information may be unstructured (Chinn & Malhotra, 2002).

The process of inquiry is a process to assist in problem solving. Unlike in school science where students are placed in a laboratory with a “cook book” experiment and asked to perform an experiment, the teacher appears more interested in the final product rather than the process that achieved the product. Authentic science experiences are different from classroom science experiences due to several factors:

- Classroom science allows for little or no reasoning or negotiation of meaning; the two constructs that are seen throughout the scientific community.
- By using reasoning, students would have the opportunities to practice argumentation, justification, and explanations (Flick, 2004).
- The time, equipment, and purpose of an investigation are quite different in a science classroom when compared to an actual authentic science experience.

The student’s experience in an authentic context can serve to reinforce the parallels with the content being learned in class while also providing a first-hand, eye-opening, and unique learning experience (Flick, 2004).

Out-of-classroom Settings

Most authentic science experiences occur outside of the classroom. These out-of-classroom or informal experiences can be in museums, science centers, or even school gardens (Braun & Reiss, 2006). Cerini, Murray, and Reiss (2003) investigated alternative strategies for learning science. They found going on a science field trip or excursion was rated as the top choice – number 1; it also was rated number 5 as a useful and effective way to learn science. What students are experiencing in the out-of-school sector greatly contrasts with what is happening in school. In an ideal out-of-classroom context, students are less constrained by school bells and the need to learn from a standardized textbook. Instead, in these more authentic out-of-classroom experiences, students are given more extensive work, which may be more difficult, but students may gain more autonomy from their work (Braun & Reiss, 2006). The science found in these out-of-classroom authentic contexts may be more exciting, challenging, and hands-on when compared to how current school science is being taught. Learning outside of the classroom involves a degree of the student's unique background and experience. For most students the out-of-classroom experience is a way to discover how science relates to their daily lives. In most out-of-classroom experiences the student is able to learn a science concept in a manner that matches with his learning. The student is not constrained by limitations set by the school science classroom. Bebbington and Nundy (2001) point out that the reason why so many students enjoy and learn from these out-of-classroom authentic experiences is that they are exposed to a range of learning opportunities that relate to larger concepts and ideas which they witness in their daily lives, such as a sunset or the flow of a stream's current. In addition, the importance of learning outside of school, especially within nature, allows students to learn conservation of the environment, to create a relationship with nature, and to enjoy physical interactivity with nature. All of these concepts work together to promote higher-order thinking. Working in a living laboratory, such as a garden, assists with the practice of observation and inference (Rennie, 2014). For many students to have an authentic science experience, they may need to leave the classroom.

Informal and Formal Contexts

The following section will discuss the terminology of formal and informal contexts and how these contexts relate to authentic experiences that can facilitate SI and the development of practices. A movement towards informal contexts, or learning in settings outside of the classroom, has gained momentum over the last decade. Support for this shift can be seen in the National Research Council (2012) and the discipline of science education (Filippoupoliti & Koliopoulos, 2014; Rennie, 2014). The researchers in the council understand the importance of experience and how an experience may lead a learner on a path of improved scientific literacy (Beichner, Saul, Abbott, Morse, Chi, Dorph & Reisman, 2016; Rennie, 2014; Sacco, Falk, & Bell, 2014). An out-of-classroom setting is a space in which learners are able to explore and to seek information for themselves (Shouse, Lewenstein, Feder, & Bell, 2010). Examples of out-of-classroom settings include: museums, science centers, gardens, zoos, and aquariums. (Beichner, Saul, Abbott, Morse, Chi, Dorph & Reisman, 2016; Kim & Dopico, 2016; Deardorff, Allain, & Risley, 2007; Brooks, 2011; Lomas & Oblinger, 2006; Montgomery, 2008; NRC, 2009; Oblinger, 2006; Schreiber, 2013; Whiteside & Fitzgerald, 2009). These are considered to be out-of-classroom settings because learners, who are outside of the traditional classroom, are typically interacting with exhibits, docents, and elements in the setting. For this dissertation, formal settings and contexts are defined as traditional classrooms where topics are segregated into subjects that do not overlap (typically biology, chemistry, or physics) and in many cases students learn the science content without connections to natural phenomena (Braun & Reiss, 2006; Gaskell, 1992). For this dissertation an out-of-classroom setting, or context is a space where science concepts are overlapping and intertwined with one another (Tobias & Duffy, 2009). The setting allows the learner to be active both physically and cognitively. The learner creates meaning from their experience (Sasson & Cohen, 2013; Tobias & Duffy, 2009).

In an out-of-classroom setting, formal learning can occur. Formal learning is defined as concepts and content that align with state and national standards, i.e., NGSS or Common Core. Many of these out-of-classroom settings have curricula that align with the authentic experience. The National Research Council (2009) created an extensive report discussing out-of-classroom settings and how they can promote learning. The report suggests that learners in these settings can learn about the nature of science, and by understanding the nature of science, the students are better prepared to develop their science practices (Bevan, Gutwill, Petrich, & Wilkinson, 2010; NRC, 2009; Rodari, 2009; Tal & Dierking, 2014). In addition, reports from both the NRC (2009) and Bell et al (2016) discuss the promise of out-of-classroom settings and how they may positively influence the understanding of nature of science and performance of scientific practices. Beyond these reports, research on the effects of out-of-classroom settings on the nature of science or nature of scientific inquiry (specifically scientific practices) is dwarfed by the amount of research on formal settings or traditional classrooms. By broadening how research is conducted for nature of scientific inquiry and scientific practices by examining out-of-classroom settings, researchers may develop a better understanding of whether out-of-classroom settings can facilitate the use of scientific practices and help students develop knowledge about the process of scientific inquiry.

The majority of research on SI and practices in out-of-classroom settings and contexts has focused on the learning outcome, e.g., content knowledge (Falk & Storksdieck, 2010; Kim & Crowley, 2010). Content knowledge is facts or information of a specific domain. Many researchers prefer to evaluate this because informal settings are designed in a manner to help learners grasp specific attributes from a specific exhibit or display (Dilli, 2016; Falk & Storksdieck, 2010; Meissner & Bogar, 2011; Schwan, Grajal, & Lewalter, 2014; Zaharia, Michael, & Chrysanthou, 2013). Adams, Gupta, and DeFelice (2012) point out that many studies in out-of-classroom settings are not designed to assess knowledge about inquiry and scientific practices; consequently, content knowledge becomes the default assessment path. Researchers and educators need to find better methods for creating research studies that evaluate all parts of inquiry and practices in informal settings instead of evaluating separate parts of the construct, such as content knowledge (Adams, Gupta, & DeFelice, 2012).

For this dissertation, an out-of-classroom setting is defined as a place where students are not sitting in their traditional science classroom. Instead, students will be participating in a separate science laboratory specific for garden education as well as working in an outdoor classroom and school garden. All of these settings are located on the school campus but are not considered to be a formal traditional classroom setting. Throughout the continuation of this dissertation the terminology of informal or out-of-school settings are used interchangeably.

Current out-of-classroom settings research

The current research in out-of-classroom settings focuses primarily on learner engagement and free choice exploration (Chi, Dorph, & Reisman 2016; Falk, 2005; Falk & Dierking, 2000, 2012). The first area, learner engagement, is investigated largely due to the fact that these settings must create exhibits or displays that can attract patrons to engage with the material (Callahan, 2012; Chi, Dorph, & Reisman, 2016). The second area, free choice exploration, is investigated because these out-of-classroom settings want to create exhibits and displays that provoke interests in patrons. Free choice learning is non-sequential, self-paced, and voluntary (Falk, 2005).

Research on free choice exploration investigates how a learner's autonomy influences learning, e.g., what attracts learners from one exhibit compared to another. Falk and Dierking (2004) created a contextual model of learning for informal venues. The theoretical framework behind their model is social constructivism (Falk & Dierking, 2012). These researchers realized that learning occurs in situated contexts (Falk & Storksdieck, 2005). Learning occurs as a dialogue between the learner and the situated environment (Falk & Dierking, 2004). Their model has considered three factors: physical, socio-cultural, and personal contexts. Together these three factors are thought to influence the learning process and its outcome (Falk & Dierking, 2004; 2018). However, Crowley and Knutson (2007) point out a gap in Falk and Dierking's model; the model created by Falk and Dierking uses only classroom learning theories. They did not consider specific conditions of informal settings such as curriculum or cognitive reflexive tasks. Schwan, Grajal, & Lewalter (2014) support Crowley and Knutson by indicating how the contextual model is lacking critical thinking by students in out-of-classroom settings in both curriculum and assessments. They discuss how hands-on exhibits or interactive exhibits are not sufficient for learning to occur and suggest that learners' minds also need engagement and reflective cognitive activities (Schwan, Grajal, & Lewalter, 2014). Callahan (2012) and Chi, Dorph, & Reisman (2016) echo the same concerns and call for research in informal settings that focuses on investigating more complex cognitive learning outcomes, like scientific practices and the process of inquiry. The NSF has addressed these concerns by funding a report discussing the impacts of informal settings and the need for more collaborative research efforts for effective evaluation (Bell et al, 2016). For effective evaluation, the design of future investigations needs to change to include learning theories from different disciplines such as educational psychology, learning sciences, and science education (Bell et al, 2016; Callahan, 2012; Kisiel & Anderson, 2010; Sacco, Falk, & Bell, 2014).

The current state of out-of-classroom setting research demonstrates that these settings allow learners to be engaged with new information and allow for the learners to choose what they want to experience (Bell, Lewenstein, Shouse, & Feder, 2009; Falk, Randol, & Dierking, 2011). However, many exhibits and displays provide shallow information where the information given has more breadth rather than depth. Rather than providing a few comprehensive exhibits, out-of-classroom settings often opt for a greater selection of exhibits that provide less information to the learner and take less time for the learner to view the exhibit (Rounds, 2004). The NRC (2009, 2012) indicates that learners want to be interactive and interested as they encounter new settings and activities. These points of interaction with settings and activities could be an intersection to help students develop knowledge about inquiry and practices. However, future studies to investigate these points of interaction and the settings themselves are needed. As recognized by several researchers, there is still a gap in informal setting research about how these settings can promote science learning, specifically nature of science inquiry and scientific practices (Callahan, 2012; Chi, Dorph & Reisman 2016; Kisiel & Anderson, 2010; Schwan, Grajal, & Lewalter, 2014; Rennie, 2014).

Other areas to consider when researching these informal contexts include: how the actual setting aligns with the content being learned, what specific learning outcomes can be found in an informal setting, and what structure curriculum or scaffolding is sufficient to create a learning experience (Rennie, 2014; Schwartz & Crawford, 2004; Schwartz, Lederman, & Crawford, 2004). In addition, current research shows that considerable scaffolding must be given in these informal settings to support higher order thinking, i.e., creating, synthesizing, analyzing. This higher order thinking can lead students to retain knowledge about the nature of science, nature of scientific inquiry, or science practices (Rennie, 2014). The use of different instructional methods such as problem-based learning, project-based learning, experiential learning, and simulations can all be embedded and aligned with informal settings (Schwartz & Crawford, 2004). But implementing these instructional methods, scaffolds, or new curricula is not enough for science learning to occur. Educators must be aware of the importance of the use of explicit meaning and reflexive thinking for science learning to occur. On one hand educators should try and be explicit when connecting content to everyday phenomena for students while, on the other hand, students need time to reflect on what they are learning and how this new knowledge connects to their everyday lives.

As Schwartz and Crawford (2004) discovered with NOS, experts, whether represented as teachers or docents, need to identify learning opportunities, and these experts must recognize the need for students to reflect and to explain their experiences (Schwartz, Lederman, & Crawford, 2004). Explicit reflexive instruction is also needed when teaching learners about NOSI and science practices. Students need to reflect on what they did at these informal settings, what they experienced, and why the practices were performed. But, as echoed by previous researchers since the early 2000s, there is a need for: better assessment in these informal settings, better curricula to take advantage of these out-of-school settings, and more consistent and systematic methodologies (Bell et al, 2016; Kisiel & Anderson, 2010; Rennie, 2014). Without reliable and validated measures, it is difficult for researchers and educators to defend the importance of out-of-school, authentic, informal experiences for developing knowledge about the nature of science, the nature of scientific inquiry, and scientific practices.

science camp studies.

In reality after reviewing the literature, summer camps were found to be an out-of-classroom setting most authentic for students to experience what professionals do in their careers. Summer camps in particular give students a full immersion experience because students are situated in a particular context, with specific activities and interactions with the context but without time constraints and grades. Summer camps allow students to explore their own interests but without the fear and risk of grades.

Four recent summer camp studies stood out as the most comparable studies to this dissertation. These four studies explored aspects of NOSI, similar to this dissertation. These four science summer camp studies were held over a one- to two-week period where students participated in different types of inquiry activities (Antink-Meyer, Bartos, Lederman, & Lederman, 2016; Leblebicioglu, et al 2017; Leblebicioglu, Metin, Capkinoglu, Cetin, Dogan, & Schwartz, 2017; Metin & Leblebicioglu, 2015).

Summer science camp studies are more similar to this dissertation than other out-of-classroom studies due to several features, including: less time constraints; activities were not graded as in school but graded on student understanding; all activities were inquiry-based and aligned with NOSI aspects; and students were immersed in an authentic setting in which they could make association.

The activities across all camps were inquiry-based, allowing the students to have agency over choices (Lederman, N., & Abd-El-Khalick, F. (1998). Furthermore, the activities were imbedded in content that was applicable to the student, i.e., ecosystems in the science camps (Abd-

El-Khalick, 2002). Activities in the science camps were engaging and relevant to the students. Students could immediately relate to the activities rather than performing labs or tasks that were difficult for the students to associate with. In addition, by using activities within the science camp setting, students were engaging in more authentic science (Crawford, 2012). Students were working with real tools and collecting their own data. They were actually working through the same process of inquiry that professional scientists and engineers do. But as expressed by Khishfe & Abd-El-Khalick (2002), if these activities and out-of-classroom settings were not explicitly discussed with students and how they were all connected, students would be unable to construct new knowledge. Students needed explicit instruction as well as time to reflect on what they were learning from performing these activities. Both of these approaches were seen in the science camps which inevitably may have been how students were able to reach mixed to informed understanding in a short amount of time. It was this authentic setting, in conjunction with aligned activities and explicit instruction, which helped promote change in the students' understanding about NOSI in these summer camps (Smith, Maclin, Houghton, & Hennessey, 2000).

However, caution is required. Authentic, out-of-classroom contexts are simply a way to help demonstrate nature of science and nature of scientific inquiry. To see change in students' understanding of SI or their practices, more astringent empirical studies investigating all aspects of the out-of-classroom setting from the students to the instructional method used and the curriculum taught must be conducted. All of these factors play a role in formal learning, i.e., structured lessons that align with state standards, to occur in an out-of-classroom setting or context.

School Gardens

School gardens are a type of out-of-classroom setting where formal learning, i.e., learning tied to government mandates curriculum, can occur (Hirschi & Sobel, 2015). This setting in the natural world provokes students to make observations and infer what is happing around them (Braund & Reiss, 2007; Trelstad, 1997). The unpredictability of the natural world allows for students to be curious and to ask questions about their experiences in this environment (Waite, 2010). The school garden should be viewed more as an extension of the traditional classroom than as a separate entity (Braund & Reiss, 2007; Waite, 2010). The out-of-classroom school garden setting allows students to experience activities that are authentic and similar to what scientists and researchers do in the real world (Braund & Reiss, 2007). In addition, using a school garden as an informal setting has its advantages because school gardens are on site, easily accessible, available most times of the year, and can be seen as a low-cost educational opportunity (Passy, 2014).

Using school gardens as a setting for education is not a new concept. School gardens have been a technique for incorporating nature and the environment into students' daily lives since the 1700s. Jean-Jacques Rousseau emphasized the importance of nature in education because the natural world is the foundation for learning about natural phenomena (Hirschi & Sobel, 2015). Johann Pestalozzi (1746-1827) and Friedrich Froebel (1782-1852) adopted Rousseau's teachings and both created schools where gardening, farming, and practical education were the basis of their teaching curriculum in Europe (Hirschi & Sobel, 2015). The largest supporter of school garden integration came from John Dewey (1859-1952) and his work with the Chicago School. He advocated for school gardens because he saw them as a living laboratory. He knew that students could not only experience situations that are found in daily life but also experience a setting that invokes investigation. Dewey understood that school gardens are laboratories where students can study growth, reproduction, soil chemistry, the role of sunlight, and many other phenomena found in the biological sciences (Dewey, 2007; Pudnup, 2008). At the Chicago

School, Dewey had his students in the “life lab,” an outdoor classroom where students had the ability to observe, to infer, and to experiment with what was naturally occurring outside. Again, students were experiencing what they were learning (Dewey, 2007; Pudnup, 2008). To Dewey and many other educators, the school garden is an extension of the traditional classroom (Dewey, 2007). The lessons taught inside can be taught outside; however, by being out in the garden, the students support their learning with authentic experiences, inquiry, and action. It may be that the connection between action and the creation of knowledge helps students learn from an outdoor classroom experience. Furthermore, school gardens are a context for situated learning. The school gardens allow students to work with one another and to work with adults in a different context then their indoor classroom. The school garden reflects the different natural phenomena that students can explore. In addition, because the students and teachers are experiencing and creating the garden together, they can share in a “situated learning” (Lave & Wenger, 1991). This shared situated learning allows students to relate and to learn from each other as well as their environment, which is the school garden (Blair, 2009; Fusco, 2001; Gaylie, 2009; Gaylie, 2011; Hirschi and Sobel, 2015; Kavanaugh, 2017; Passy, 2012; Williams & Dixon, 2013; Williams & Brown, 2013). The school garden may be a setting where situated learning can be facilitated between the students, the teacher, and activities that relate to the school the garden.

School Gardens in the United States

The implementation of school gardens has occurred in waves in the United States. Specifically, school gardens have been a part of this country’s history in three waves occurring during the World Wars, the 1970s environmental movement, and the late 1990s with the inquiry education movement. Toward the end of the 19th century, more school gardens were being raised in large urban centers such a Boston and New York City; however, the school gardens were not viewed as educational tools. On the contrary, the school gardens were placed in these urban schools for students to view and discover natural beauty. Therefore, early on in American schools, school gardens were desired for their aesthetic reasons rather than educational reasons (Pudnup, 2008).

The first wave of the school garden effort in America began in the middle of World War I. School gardens began appearing across school districts from rural to suburban to urban areas. President Woodrow Wilson made a proclamation in 1916 for the commitment of schools and students to these gardens for the production of food for their communities (Gaylie, 2009, 2011). Again, by the middle of WWII, school gardens, also known then as “victory gardens,” made a resurgence. However, as the war ended, the growing of school gardens greatly diminished (Gaylie, 2009, 2011; Hirschi & Sobel, 2015).

The second wave of school gardens occurred from 1964 to 1975, during the “environmental movement” (Gaylie, 2009, 2011; Williams & Brown, 2013). During this time, the United States had become more interested and concerned with the environment and how to protect nature. School gardens were seen as a link between education and environmental understanding (Williams & Brown, 2013). However, due to societal factors, i.e., the Vietnam War, the recession occurring in the United States in the late 1970s and early 1980s, school gardens did not gain a supportive footing in education systems and were again displaced.

The third wave of school gardens in the United States occurred in the mid-1990s. During this time, the support for school garden efforts was being proclaimed from several directions, including ecologists, environmental scientists, developmental psychologists, educators, and nutritionists. By this time, experts were identifying the need for students to experience nature to develop a relationship with the environment (Orr, 1992). School gardens were seen as an avenue to help to create or to strengthen this connection with the environment. In 1995, Delaine Eastin, then State Superintendent of Public Instruction, California Department of Education, launched “a garden in every school initiative.” She was the first of many educators who acknowledged that school gardens could provide opportunities for students to improve their knowledge across several domains (Hazzard, Moreno, Beall, & Zidenberg - Cherr, 2011). Since the mid-1990s, school gardens have expanded and been viewed as a setting where academic learning can occur, a place for students to build a relationship with nature, and a place for students to learn the value of health (Gaylie, 2009, 2011; Williams & Brown, 2013). Several successful garden programs have been established across the United States: Edible Schoolyard in Berkeley, California; City Sprouts in Cambridge, Massachusetts; Slow Food USA National School Garden Program with their beginnings in Brooklyn, New York; The Boston Schoolyard Initiative (BSI) in Boston Public schools; and REAL School Gardens (RSG) Dallas/Fort-Worth, Texas (Hazzard, Moreno, Beall, & Zidenberg - Cherr, 2012; Hirschi & Sobel, 2015; Passy, 2014). All of these programs have been assessed by a third-party evaluator to demonstrate that students in these garden programs can learn content knowledge, environmental stewardship, nutritional knowledge, or improved well-being (Hirschi & Sobel, 2015).

Current school garden research

In the last twenty years, school garden research has demonstrated many benefits for the students who participate in school garden programs. The majority of current school garden research focuses on three areas: academic achievement, attitudes and behaviors toward the environment, and health and well-being (Kavanaugh, 2017).

The largest field of current school garden research investigation is academic achievement (Williams & Dixon, 2013). Academic achievement primarily includes the learning of content knowledge over several academic domains: science (Fusco, 2001; Klemmer, Waliczek, & Zajicek, 2005; McArthur, Hill, Trammel, & Morris, 2010; Pigg, Waliczek, & Zajicek, 2006), math (Pigg, Waliczek, & Zajicek, 2006); language arts (Cutter-Mackenzie, 2009; Fleener, Robinson, Williams, & Kraska, 2011); environmental science (Aguilar, Waliczek, & Zajicek, 2008; Skelly & Bradley, 2000; Skelly & Zajicek, 1998); sustainability (Krash, Bush, Hinson, & Blanchard, 2009); and conservation (Skelly & Zajicek, 1998). Content knowledge may be the construct most investigated because a school garden curriculum can be designed to be specific and touch on knowledge that is connected to the one subject being taught at the time. This is also the main reason why the majority of this research cannot be generalizable. The curriculum is not consistent between garden programs, subject areas, grades, or even states. The investigation of content knowledge can demonstrate only one aspect of how school gardens can be an effective setting for formal learning to occur.

As emphasized in the second wave of school garden movement, this setting creates a situation where students' attitudes and behaviors about the environment can be investigated. Many researchers are interested in how the garden affects students' connection with nature (Williams & Brown, 2013). Does the experience in the garden help change the students' attitudes about the environment (Skelly & Zajicek, 1998; Waliczek & Zajicek, 1999), behaviors about saving the planet (Koch, Waliczek, & Zajicek, 2006), and students' understanding about environmental stewardship (Aguilar, Waliczek, & Zajicek, 2008; Cutter-Mackenzie, 2009; Krash, Bush, Hinson, & Blanchard, 2009)? In this area, researchers are interested in how students adopt a "greener and more sustainable lifestyle. This area of environmental attitudes and behavior's research has branched out into citizen science. Citizen science can explore how students understand how a project can help a community, specifically environmental projects such as a school garden (Fusco, 2001; Pudup, 2007).

The largest area where school gardens have impacted students is in the area of health and well-being (Ozer, 2007; Robinson & Zajicek, 2005). Health can be viewed as an individual's understanding about nutrition and knowledge about food. Many studies have looked at overall nutritional knowledge (Beckman & Smith, 2008; Evans et al, 2012; Graham, Beall, Lussier, McLaughlin, & Zidenberg-Cherr, 2005; Koch, Waliczek, & Zajicek, 2006; O'Brien & Shoemaker, 2006; Turner, Eliason, Sandoval, & Chaloupka, 2016) or more specifically, the consumption and knowledge of fruits and vegetables (Cotugna, Manning, & DiDomenico, 2012; Morgan, Warren, Lubans, Saunders, Quick, & Collins, 2010; Ratcliffe, Merrigan, Rogers, & Goldberg, 2011). These health studies are important because students learn where the food which they consume comes from. Also, students begin to see how nutrition plays into their everyday lives and why healthy food choices are important for growth and development (Ratcliffe, Merrigan, Rogers, & Goldberg, 2011). The other area to school garden health research is overall well-being (Fleener, Robinson, Williams, & Kraska, 2011; Ozer, 2007). Well-being describes an individual's mental, physical, and emotional state of mind. Ozer (2007) was able to demonstrate how working in a school garden helped students gain a more positive outlook at school and create bonds and relationships with others. School gardens have been able to change how students feel in their daily lives.

One study conducted by Williamson and Smoak (1999) explored the environmental science program called "Down to Earth". This program emphasized the garden as a place for more hands-on learning, problem-solving, and critical thinking. The instructional design, curriculum, and the emphasis of the scientific method were too antiquated for students. However, this was the only study that researched school gardens from the larger perspective of problem-solving and critical thinking skills, rather than simply focusing on one of the three previously mentioned areas (academic content knowledge, attitudes and behaviors, and health and well-being).

Comprehensive reviews of school garden research in America have been conducted by various researchers: Ozer (2007), Blaire (2009), Williams and Dixon (2013), and Kavanaugh (2017). All four groups of researchers support the benefits of school gardens. Williams and Dixon (2013) conducted a comprehensive review for the last twenty years of school garden research. They reported that 93% of students improved in their science achievement, 80% of students improved in math, and 72% improved in language arts. Nevertheless, just as Ozer (2007) and Blair (2009) stated in their reviews of the literature, more rigorous research needs to be conducted on this topic from two perspectives: curriculum design and methodology. Williams and Dixon (2013) echo this message in their review, but they went a step further and emphasized specific areas in methodology and curriculum that needed to be improved. Less than half of the studies reviewed by Williams and Dixon (2013) report validity or reliability about measures used or created. They also point out how the majority of studies include participants who self-reported rather than using quantifiable items. Williams and Dixon (2013) emphasize more design and development in school garden instructional activities and curricula that align with state and national standards. Ozer (2007) calls for a combination of consistent, systematic, qualitative and quantitative methods with direct observation of instruction and implementation. These are only the beginning of many other methodological problems found across school garden studies. In addition, research should be bolstered by more short-term, quasi-experimental studies, longitudinal studies, the use of comparison groups, and research should investigate more than the three usual areas of academic achievement, environmental attitudes and behaviors, and health and well-being.

More rigorous research needs to be conducted for school garden research to gain credibility in the education community.

Gaps in school garden research

Many teachers and schools do not see the larger opportunity for learning that a school garden can provide for students. Most teachers and administrators focus on the garden as a content-specific or domain-driven setting. They fail to see the big picture impact. As Dewey proclaimed, school gardens are a place for science practices to be developed and a place where knowledge about the process of inquiry can form (Dewey, 2007). As expressed in NGSS (Lead States, 2013) and the Framework for K-12 Science Education (NRC, 2012b), inquiry and practices are not specific only to one science discipline, but instead these practices and knowledge about the process of inquiry are found across disciplines. The school garden can facilitate the understanding and knowledge of SI and practices across disciplines, but school garden research has yet to focus on the bigger picture of practices. The focus of the school garden curriculum has been specific to content knowledge: science, math, language arts, nutrition, and health (Gaylie, 2009, 2011; Hirschi & Sobel, 2015).

After an extensive literature review, it became apparent that most school garden research did not investigate how the school garden could facilitate inquiry understanding and practices with students. This gap demonstrates the need to investigate whether school gardens can be a type of outdoor classroom where inquiry and practices can be modeled by teachers and internalized by students. The literature also points out the need for a more systematic approach to evaluate school gardens both methodologically and by curriculum design. This dissertation will add to the body of school garden literature examining whether school gardens can be a place to help students learn investigation practices and to understand the knowledge behind the practices.

School gardens do not only need to be used for content knowledge, attitudes and behaviors, and health and well-being. The school gardens are an informal setting where formal learning can occur. This research will support the idea that a school garden is a living laboratory where natural phenomena can be witnessed and the location for planning and implementing investigations where students think scientifically. These authentic experiences in the school garden allow students to practice similar skill sets which experts in different science disciplines also do in their professions. Furthermore, the curriculum design and reliability and validation of instruments used throughout this school garden intervention will provide much needed support for why more consistent methodologies, valid and reliable measures, and standard-aligned curricula should be used when conducting school garden research.

The current state of both informal setting and school garden research is ripe for investigating how informal settings such as a school garden can be an environment where teachers can model scientific practices and the process of scientific inquiry while serving as the place where students can learn to adopt these practices and develop knowledge about inquiry and how the process of inquiry is a form of problem solving.

Project-Based Learning

One way to engage students with scientific practices and the process of inquiry is through the instructional method of project-based learning (Crawford, 2014). This dissertation is specifically implementing project-based learning (PjBL), a type of student-centered learning approach. The PjBL approach can be used universally with all students and in all domains from literature to math; this method of instruction can be easily tweaked to match a desired domain (Blumenfeld, et al, 1991; Larmer, Mergendoller & Boss, 2015). In a PjBL unit, students are asked a question that they can relate to in their daily lives. From this question, students are asked how to find a solution (Krajcik & Blumenfeld, 2006; Larmer, Mergendoller, & Boss, 2015). Students learn how to plan and how to investigate a question in an authentic experience (Barron et al, 1991). They also participate in collaborative learning. Students construct a solution to the posed question with the aid of a project. This project allows for students to create meaningful associations with new knowledge (DeFillippi, 2001). Students' progress from asking questions to the act of doing, solving the problem themselves, and constructing a solution (Krajcik & Blumendel, 2006). This type of intervention uses hands-on experiences for the learner to integrate new information into knowledge structures that they already have established (Bell, 2010). The largest difference in this type of intervention compared to others is that a type of model or product, whether physical or conceptual, is created to explain the learner's findings (Kelly, 2014; Bloom, 2015). PjBL encompasses both socio-cultural and situated learning theories (Krajcik & Blumenfeld, 2006). In socio-cultural theory, adults guide students to what should be learned (Vygotsky, 1978, 1987, 1997). This can be seen with the teachers aiding students. Moreover, Vygotsky (1978) demonstrated that the use of artifacts can facilitate learning. An artifact can be almost anything, i.e., a book, a calculator, or a garden. Recall from the introduction that the theoretical framework of situated learning was introduced because this framework allows the learner to use actions with others and the environment to understand new information (Boyles, 2006; Dewey, 1912, 1938; Lave, 1988). PjBL aligns well with situated learning because the project is situated in a specific context. The context and project are the driving forces for learning. The learner is acting out the process that the learner is trying to solve when participating in PjBL; for instance, if the project asks "how to create a more efficient recycling factory," the learner can cognitively situate themselves to frame their thought in this new context for example an engineer in a recycling factory. This situated learning allows the learner to create direct connections between the problem they are trying to solve and how they themselves could gain new knowledge from the situated context (Lave & Wagner, 1991). Dewey used this approach of situated learning to help drive students from a cognitive as well as a hands-on learning (Dewey, 1917). The student has the ability to experiment with all variables and to find answers through the use of action in the situated context (Lave, 1988).

In addition, PjBL aligns with out-of-classroom learning; both ask for students to be immersed in an authentic experience. During an authentic experience, the learner is typically engaged with the environment. The engagement with the environment plays a key role as it leads to reciprocal causation (Bandura 1989). Reciprocal causation is between the authentic situated learning environment, the artifacts found in the environment, and the learner (Bandura, 1989, 2008). Learners and their environments mutually influence each other. (Bandura, 1989, 2008). The learner has agency over how the environment may affect him, and this constant action with the environment and individuals in the environment allows for situated learning to occur (Schwartz, Lederman, & Crawford, 2004; Lave, 1988). In a PjBL unit, students yield an end product. Through this end product the students feel that they themselves have more control, agency, over their learning and how they learned through their authentically-situated experience.

By allowing students to learn and to practice science in an environment that is parallel with the science content being taught in a typical classroom, students may create stronger associations with science concepts and science processes by experiencing science in an environment that matches what is being learned in a current unit of study. In addition, by learning in an environment that ties to the curriculum, students will have visual and tactile associations along with what is being taught to them orally. Moreover, by actually moving and using hands-on learning, students may continue to create deeper connections with new concepts and theories because of their ability to actively investigate the action of the science process or content that is being taught, e.g., photosynthesis, soil composition, and ecosystems (Choi & Hannafin, 1995). It may be the case that, as an intervention, a PjBL unit can facilitate better science learning, especially when investigating inquiry knowledge and practices.

Project Based-Learning with Scientific Inquiry

The primary location of this dissertation will be a school garden, which is defined as an out-of-classroom setting because students are leaving their typical science classrooms to work in an outdoor classroom and science laboratory. The focus of the PjBL units is the integration of knowledge with the process of scientific inquiry and the creation of an end product or solution; this instructional method parallels that and has the same emphasis as the NGSS (Lead States, 2013).

Over the last decade, more PjBL units in out-of-classroom settings have become incorporated into middle school science curricula. Current research demonstrates that project-based learning and problem-based learning (PBL) effectively facilitate student learning. A meta-analysis conducted by Dochy, Segers, Van den Bossche, and Gijbels (2003) on 43 articles found a strong positive effect size (*ES* = 0.46), suggesting the PjBL and PBL increases student learning beyond that of traditional lecture-based classes at the post-secondary level. This finding was confirmed by Walker and Leary (2009). However, note that Strobel and van Barneveld (2009) suggest that PjBL and PBL are effective only under certain conditions, e.g., settings. It may be the case that exposure to a science inquiry unit in a school garden will help influence an individual to engage in and to understand scientific inquiry knowledge and practices. Researchers and educators must understand how these learning methods and informal settings affect students. This is especially important to school gardens set in middle schools where little to no empirical studies have been conducted. It may be the case that by performing a PjBL unit in a school garden, students' scientific practices and knowledge about scientific inquiry may change in ways that are different from what happens in typical classroom settings.

Over the last decade, school gardens have been used to promote better nutrition and health habits in students (Gato, 2012; Ratcliffe, Merrigan, Rogers, & Goldberg, 2011), to promote pro-environmental attitudes (Williams & Dixon, 2013), and to teach environmental education (Williams & Dixon, 2013). However, little research has specifically looked at how a school garden can be adapted as a model to promote nature of scientific inquiry and the practices associated with inquiry. Currently, there is a gap in the literature informing educators and researchers about how a school garden could be considered to be a living laboratory to help promote and to facilitate SI knowledge and practices in students.

If researchers can understand the *how*, then they have the ability to implement changes to several systems from education, to policy, to informal setting design. This could provide students with the best possibility of knowledge acquisition in the constructs of SI and practices. Research from both the learning sciences and science education has demonstrated how formal settings contribute to the nature of scientific inquiry and scientific practices. Learners can develop knowledge about inquiry through various instructional and design methods in these formal settings. More empirical studies with the intention to understand how students gain knowledge about SI and practices in an informal setting need to be conducted. On a broader scale, this research can inform the public about how the nature of science and the nature of scientific inquiry is occurring in informal settings. This could subsequently impact policy, design of informal venues, and curricula in place at informal settings. As the NRC (2009, 2012a, 2012b) states, informal settings may help learners become better informed citizens and individuals who are more adept problem solvers and consumers of science, thereby helping citizens to become more scientifically literate (Roberts & Bybee, 2014). This dissertation will add to the literature by investigating how an out-of-classroom setting can facilitate knowledge about SI and the practices performed throughout the process of inquiry.

Implications and Future Research

Based on the literature discussed in this chapter, a school garden inquiry investigation unit was created for a middle school science class. This school garden inquiry investigation exposed students to Next Generation Science Standard practices in addition to Nature of Science Inquiry aspects. This dissertation investigated the nature of SI and practices specifically through Next Generation Science Standard practices demonstrated during a ten-week school garden project-based learning inquiry unit with sixth grade students enrolled in science courses at an urban middle school. The purpose of this research is to investigate two areas: whether knowledge of and understanding of SI and practices can be developed when learning in an informal garden setting with curriculum and how these practices help create knowledge about the process of inquiry. The specific research questions that will guide this research are:

1). How does participating in the school garden inquiry unit affect students' scientific practices?

2). How does participating in the school garden inquiry unit affect students' knowledge and understanding about science inquiry?

3 METHODOLOGY

Theoretical Framework

Over the last two decades, researchers in education and psychology have begun to take a more mixed-methods approach to investigating humans because of the complexity of the interactions of human emotions and reasoning. Mixed-methods is a type of research that involves both analyzing and integrating quantitative data, e.g., experiments or survey, and qualitative data, e.g., interviews, focus groups, and field notes. This approach allows researchers to understand the human participant more holistically (Cameron, 2011). There is not a specific paradigm that encompassed both quantitative and qualitative methods (Johnson & Onwuegbuzie, 2004). The researcher has chosen to conduct the study using the paradigm of constructivism.

constructivism.

In order to address the influence of individualistic thinking, learner prior experiences, and relationships with objects or ideas, constructivism has been selected as a guiding paradigm for the research in this dissertation (Crotty, 1998). Constructivism is a paradigm in which learning is an active, constructive process in which learners construct new knowledge from prior knowledge and experiences (Matthews, 2002). Therefore, mental representations are subjective for each individual (Matthews, 2002). Each person has a different interpretation and process in the construction of knowledge. The learner brings past experiences and cultural factors to a situation (Vygotsky, 1997). Constructivism assumes that all knowledge is constructed from the learner's previous knowledge, regardless of how one is taught (Vygotsky, 1978). Thus, even listening to a peer involves active attempts to construct new knowledge; just as participating in dialogue with a peer may construct new knowledge. Moreover, in this paradigm, learners continuously test their ideas through social negotiation (Schcolnik, Kol, & Abarbanel, 2006). Crotty (1998) identified several assumptions about the process of learning under constructivism: meaning is created as an individual engages with the world that he/she is interpreting; individuals engage with their world and make sense of it based on their own historical and social perspectives; and the generation of meaning is social, arising due to interactions within specific communities.

There are two main approaches to constructivism: cognitive constructivism and social constructivism. The approaches are not mutually exclusive but complement and support how an individual can construct new knowledge. However, the two approaches are fundamentally different from each other due to the lens which an individual uses. Jean Piaget, a developmental cognitive psychologist, first discussed the cognitive constructionist approach. He focused on the importance of the mind in learning. Lev Vygotsky, a psychologist, focused on the effect of social interaction on learning (Vygotsky, 1997).

Through Piaget's lens, individuals are always accommodating or assimilating new information in their minds. Piaget explained that individuals use their cognitive structures, working memory, and long-term memory to interpret and to understand information (Bachtold, 2013). When individuals encounter new information, they use their cognitive structures to assimilate the new information into an existing schema. With time, the assimilated new information modifies the existing cognitive structures. Therefore, the cognitive structures are accommodating to the new information or environment. There is continuous interplay between mind and environment; cognitive structures are always constructing new knowledge (Bachtold, 2013).

Vygotsky did not deny the role of cognition in the individual but rather argued that interpersonal learning comes before intrapersonal learning (Bachtols, 2013). Vygotsky emphasized the importance of social cognition and the effect of social interaction on the construction of new knowledge (Vygotsky, 1978). He claimed that one cannot try to understand how an individual thinks' without taking into consideration the cultural context in which an individual's thoughts develop (Bachtols, 2013). Because constructivism depends upon the intertwining of cognitive and cultural influences, it has laid the foundation to better understand how context and setting affect learning.

Conceptual Framework

In Chapter One, four constructs were discussed: scientific inquiry, NGSS/NOSI, out-of-classroom settings, and the actions and behaviors which professional scientists and engineers perform in their everyday lives. These constructs create the conceptual framework for this dissertation see Figure 2 below.

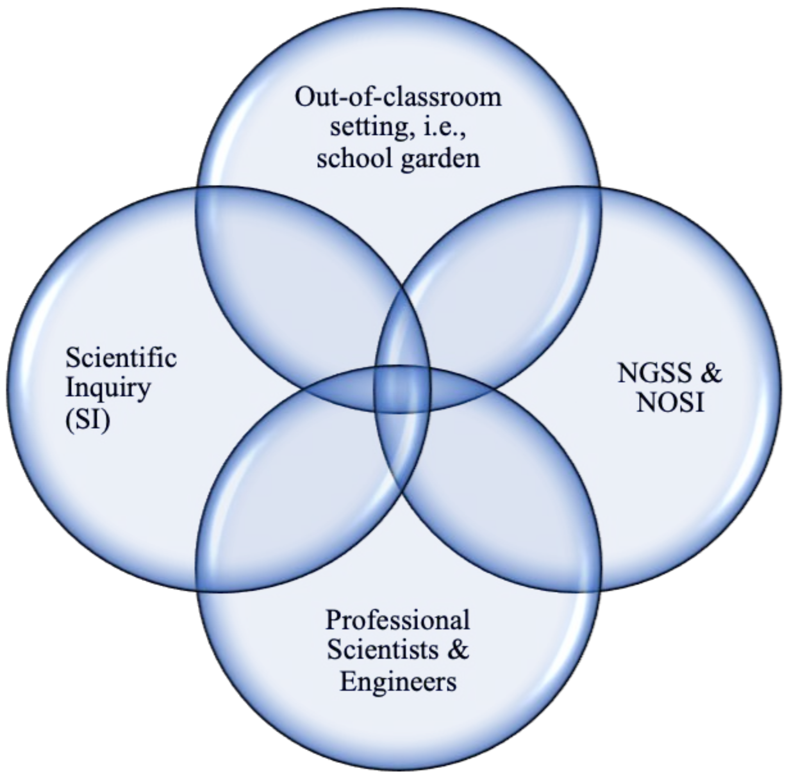


Figure 2. *Venn diagram representing the four constructs and how each have a role in the intervention. The intersect of these constructs is circled in red.*

These four constructs all play a role in how the intervention was designed. The out-of-classroom setting, i.e., school garden, is an authentic site for students to perform the process of scientific inquiry. The school garden allows students to witness natural phenomena as well as create connections between prior knowledge and new knowledge. In addition, the students are participating in activities that connect both NGSS practices with the NOSI aspects. As the students are exposed to and immersed in the process of scientific inquiry by participating in these activities, the students are actually behaving and acting as professional scientists and engineers. This direct connection between what the students are doing and learning and what professionals do gives students a better perspective in how they see themselves in a future science or engineering career. That is why these four constructs are intertwined with one another for this dissertation. All four constructs play different but vital roles in how a student learns from this type of out-of-classroom intervention.

The paradigm and the conceptual framework discussed allow for the research to proceed with a mixed-method approach; constructivism facilitates critical inquiry of how to solve a problem or design an investigation with the understanding that individuals come with their own biases and experiences. In addition, with the support of constructivism, the research can further investigate how individuals' cognitive and social differences can influence how an individual creates or understands new knowledge. The conceptual framework will allow investigation of the students' interactions with the setting, with each other, and with the artifacts in the setting.

The research performed in this dissertation is based on the belief that the authentic experiences of the student participants are unique, compared to their traditional school counterparts or students participating in an out-of-classroom setting without a structured curriculum. Constructivism and my conceptual framework will be essential for framing this research. Data collection is focused on understanding students' authentic experiences in an out-of-classroom setting, i.e., a school garden. In order to obtain richer participant information, the participants' interviews explored their experiences in the informal setting as well as their understanding of science practices and the process of scientific inquiry. By understanding how setting can affect an individual's view on inquiry and scientific practices, the researcher can devise educational interventions that support students' facilitation of scientific practices.

The research conducted for this dissertation is mixed-method because such a multi-faceted approach is required to answer the two primary research questions:

1). How does participating in the school garden inquiry unit affect students' understanding about science inquiry?

2). How does participating in the school garden inquiry unit affect students' scientific practices?

It may be in the best interests for research in out-of-classroom settings to conduct studies that use a mixed methods approach, incorporating both quantitative and qualitative components (Kim & Dopico, 2016). The use of both types of data sets can provide a better representation of the investigation and the participants. Qualitative work allows researchers to gain a more comprehensive understanding of a participant's response (Gillespie & Melber, 2014; Taylor, 2014). Researchers should investigate participation in an activity at an out-of-classroom setting compared to students who did not participate at an out-of-classroom setting to determine whether the setting affected the participant's learning, and then the researchers could compare the groups for statistical differences (Sturm & Bogner, 2010).

A mixed-method approach is best for this line of research because the data being collected is from two types of data sources: quantitative and qualitative (Cresswell & Clark, 2011). The mixed-method approach is implemented because this method allows implementation of qualitative and quantitative strands simultaneously during the research process (Cresswell & Clark, 2017).

As stated, the theory guiding this research is constructivism. In addition, the conceptual framework created also guided the research, see Figure 1. The chosen epistemology and created conceptual framework focus on the individual's experience and how the individual creates meaning from an object or event. The use of a mixed-methods design allows gathering of both quantitative and qualitative data about the students' experience throughout the school garden inquiry unit. Each type of data source is needed because it gives one perspective of each participant's experience, and when considered together, the sources create a more holistic view of each participant. In addition, each data source is for a particular construct: scientific practices and knowledge about inquiry. The quantitative data gives a broader understanding of what level of application the students possess about their scientific practices. The qualitative data can give a deeper understanding of what the participants are experiencing and their understanding about the process and nature of inquiry that occurs during an investigation (Creswell, 2005).

As discussed in this section, a mixed-methods design is the best research design for this dissertation. The quantitative data collected cannot be fully interpreted without the qualitative data; both data sources are needed to create a richer more meaningful understanding of each student participant's application and views on science practices (Cresswall & Clark, 2011, 2017; Gay, Mills & Airasian, 2009).

Context of Study

This study was conducted in an urban context. An urban context is defined as 2,500 to 50,000 people found in a populated area or 1,000 people found per square mile (urban context, www.census.gov). In addition, the participating school is a middle-school made up of 769 students with 97.6% of the school demographic being African-American. The school is 50% male and 50% female, and 57.9% of the school is eligible to participate in the National School Lunch Program (NSLP, www.benefits.gov). 48.6% of the students receive free lunch, and 9.3% receiving reduced lunch (Dekalb County, www.ga.us). To qualify for free lunch, a student's family annual income must be under $15,171 in 2015 (NSLP,www.benefits.gov). To qualify for reduced lunch, a student's family annual income must be below $21,590 in 2015 (NSLP, www.benefits.gov). Due to these school factors of socio-economic status, the participating school is characterized as a Title 1 school; it receives federal grants to fund the school (Title 1, www.ed.gov). The Title 1 status is the primary reason for conducting my dissertation research at this school; a school garden intervention would help expand the school's ability to produce food while complementing students' experiences and knowledge with nutrition and healthy eating choices.

school and community.

The school for this study is found in an area which is populated by food deserts. Food deserts are locations where it is difficult for families to purchase perishable items such as vegetables and meats. Instead, neighbors are found in areas of isolation where the closest grocery store is miles away. Because perishable items are more difficult to get, many individuals in these communities experience poor nutrition. Furthermore, because they live in a food desert, some individuals do not even recognize fresh food. Due to the location of the participating school, the intervention was designed around the main idea of "how to stop world hunger." From this larger idea, the researcher helped the students discover that they themselves could help their community. The intervention tried to inform students that they have the ability to create change in their community even as small as a school garden.

From an individual level, the researcher wanted to empower the students from this low-income community. The researcher wanted to expose students to different forms of agriculture and ecology; thereby giving students new knowledge sources which they could share with their parents or contribute to the community. The goal was that in the future these students could walk into a store and have the ability to identify different produce and other forms of nutrition.

Finally, the majority of the students living in this community do not have a strong connection with nature. With this intervention the researcher exposed students to nature and how they fit into the natural world. By being exposed and immersed in nature through this intervention, the researcher hoped that the students would develop an appreciation and respect for the natural world.

Design of the Study

This study employed an exploratory intervention strategy defined by a data collection period at the beginning and at the end of the exploratory intervention (see Table 1). An intervention is defined as a designated time period in which students are exposed to or experience new information or ways of learning which can promote or facilitate learning in a particular domain (Clements et al, 2011). The intervention will consist of five inquiry garden lessons; students had the ability to practice their inquiry practices and their knowledge about gardens during the intervention.

Current Study

The following describes the context for this dissertation study which took place in Spring 2018.

participants.

This study focused on adolescents because the adolescent brain undergoes many physiological and psychological changes. An adolescent's brain is maturing, which allows him/her to understand and comprehend new information (Choudhury, Blakemore, & Charman, 2006; Giedd, Stockman, Weddle, Liverpool, Wallace, Lee, Lalonde, & Lenroot, 2012; Mills, Lalonde, Clasen, Giedd, & Blakemore, 2012; Sisk & Foster, 2004; Steinberg,Vadell, & Bornstein, 2011). Therefore, during this stage of life, adolescents may develop better problem-solving skills, critical thinking skills, organization, and self-reflection (Reyna, Chapman, Dougherty, & Confrey, 2012). At this age, the brain has achieved the ability to think abstractly and logically, allowing the development of scientific inquiry, including, but not limited to, the scientific practices and knowledge about the nature of science inquiry.

In addition to adolescents being the target age range, middle-schoolers were specifically chosen for this study because middle school is when many students are exposed to more content-driven science units rather than general overviews that occur in elementary school (NGSS, 2013). Due to state level curricula, this dissertation focused on Georgia state middle grade level curriculum. In the state of Georgia, sixth grade science class curricula content is focused on earth science; seventh grade is focused on life science; and eighth grade is focused on physical science. Participating students were drawn from sixth grade science classes in an urban middle-school located in a large district in the Southeast of the United States. Both groups of students learned the third unit found in the Georgia middle-school sequence on earth and soil. Students in both groups were exposed to curriculum that is in line with the Science Georgia Standards of Excellence (www.georgiastandards.org) and Next Generation Science Standards (NGSS Lead States, 2013), but the lessons and activities were different between treatment and comparison groups.

treatment group.

Two treatment classes from sixth grade participated. The treatment classes participated in the school garden during their normal daily science class over an eight-week period for a total of 25 instructional days. The researcher taught each treatment class for a fifty-five-minute period on Mondays, Tuesday, Wednesdays, and Fridays. On Thursdays, the lead science teacher from the school, reviewed what the researcher taught the previous days. Students in the treatment classes were exposed to a total of 23.1 hours of the intervention. These students participated in inquiry activities in groups of four or five as well as direct and explicit instruction by the researcher. All documents that treatment group students received can be found in the materials section.

comparison group.

One comparison class from sixth grade participated. The researcher was only allowed in the comparison group classroom for the post-test. The researcher was not able to observe the comparison class teacher during her science lessons. The comparison group teacher taught the same standards as the researcher; however, no observation sheets were filled out for the comparison teacher. The researcher could only speculate about what was taught in the comparison group classroom.

materials.

school garden PjBL inquiry lessons. (see Appendix A)

All students participating in the treatment classes used a curriculum created and taught by the researcher. This curriculum was school-garden oriented with learning outcomes aligned with the Next Generation Science Standards for the three constructs: science and engineering practices, disciplinary core ideas, and crosscutting concepts (Lead States NGSS, 2013). In addition, integrated within the lessons were the eight aspects of the SI: 1) questions guide investigations, 2) multiple methods of scientific investigations, 3) inquiry procedures are guided by the question asked, 4) all scientists performing the same procedures may not get the same results, 5) inquiry procedures can influence results, 6) sources, roles of, and distinctions between scientific data and scientific evidence, 7) research conclusions must be consistent with data collected, and 8) explanations are developed from a combination of collected data and what is already known (Lederman et al, 2014; Schwartz, Lederman & Lederman, 2008). The NGSS and eight aspects of the SI were explicitly explained and discussed throughout the lessons with the students. These explicit cues were needed for students to internalize and to apply this information to their own investigations (Lederman et al, 2014; Schwartz & Lederman, 2002; Schwartz, Lederman, & Lederman, 2008). Students needed to understand that the practices were not to be conducted in a linear fashion but more like a string in part of a complex web. As students started to participate in different inquiry units, they noticed that their methods for inquiry changed due to the setting or context.

All of the lessons connected to the broad overarching question that was posed to the treatment classes on the first day, “How can we solve world hunger?”. From this large question the researcher guided students into a more attainable goal, “How can we help solve hunger in our community?” Throughout the lessons the researcher helped students connect with the broader question, helping to solve hunger in their community. The five garden lessons included: how to begin an investigation about world hunger, surveying the land, how to investigate which plants to grow, how to plant, and how to engineer a garden constructed from recyclables (see Appendix A). All five garden-inquiry lessons were project-based, allowing students to create solutions to STEM-affiliated problems. Lessons included open-ended questions and activities for students to complete.

Each lesson duration ranged from one class period to three class periods. The lessons were flexible with respect to class time to allow students more time to perform authentic scientific inquiry. Students completed five school garden PjBL inquiry lessons before the post-test measure was taken. All lessons were validated with the treatment class teacher, middle-school science coach, and a science educator at the university. All three parties critiqued and made suggestions with respect to where to change the garden inquiry lessons. Garden inquiry lessons were not taught until all three parties approved the five lessons.

lesson worksheets.

Throughout each lesson, students were given open-ended questions and worksheets to complete and place in their field notebooks during their garden experience (see Appendix B). These questions and worksheets stimulated students to think critically about their investigation and what scientific practices and knowledge about inquiry were being used in the day's lesson. All lesson questions and worksheets were validated with the science coach, the treatment class teacher, and science educator at the university. All three parties critiqued and made suggestions to improve the garden lesson prompts for treatment group students.

field notes and photographs

During each lesson, the researcher took field notes and photographs as the students completed the lesson prompts and lesson activities. Notes were written according to level of interaction: student-with-student, student-with-teacher, student-with-researcher, and student by himself.

Notes were taken each day when a lesson was taught. Photographs were also taken throughout the intervention. The photographs showed the level of interaction: student-with-student, student-with-teacher, student-with-researcher, and student by himself as well as the practices engaged with by the students.

***fidelity worksheets* (Inquiry Analysis Tool).**

To ensure that all five lessons were taught with fidelity, the researcher was observed by the following individuals: a science coach from the middle-school, a sixth-grade science teacher from the middle school, and a visiting professor from a large southeastern university. Each individual completed a fidelity worksheet adapted by Volkmann and Abell (2003) (see Inquiry Analysis Tool, Appendix E). This fidelity worksheet validated that the researcher was actively instructing the treatment group students with the correct curriculum for each specified lesson, see Table 4 below.

The fidelity sheet is divided into six areas: 1. Engage learners in scientifically-oriented questions; 2. Ask learners to give priority to data/evidence; 3. Encourage learners to create and design investigations from research; 4. Discuss with learners subjectiveness and tentativeness of science; 5. Expect learners to communicate and justify their proposed designs, investigations, and explanations; and 6. Discuss with learners the importance of modeling in science. Across all six areas, more detailed sub-questions were asked. As the lesson was being taught, the researcher was being observed and evaluated with the fidelity tool. According to the fidelity tool there are three options for demonstrating that a concept was taught to the class: yes, it was taught, no it was not taught, or it was not applicable. Furthermore, not all six areas on the fidelity sheet were seen in every lesson.

Table 4. *Inquiry Analysis Tool (modified)* (Volkmann & Abell, 2003)

Does the material/lesson:	Yes	No	N/A
1. Engage learners in scientifically-oriented questions?			
- Do questions guide inquiry?			
- Are questions relevant to students?			
- Do students understand that investigations start with a guiding question?			
2. Ask learners to give priority to data/evidence?			
- Do students understand the difference between data and evidence?			
- Do students use their senses and instruments to collect data?			
- Are students taught that different individuals can collect different data due to different methodologies?			
- Do students evaluate the data they are gathering?			
3. Encourage learners to create and design investigations from research?			
- Are students encouraged to design their own investigations?			
- Do students base their investigations from research?			
- Are students asked to explain their reasoning for the design of their investigation?			
- Do students plan and organize their investigations?			
4. Discuss with learners subjectiveness and tentativeness of science?			
- Do students understand that each group may have different procedures and conclusions?			
- Do students understand that creativity and imagination are used in science?			
- Do students understand that science can change due to new discoveries and technology?			
5. Expect learners to communicate and justify their proposed designs, investigations, and explanations?			
- Do students have opportunities to discuss their ideas in small groups?			
- Do students have opportunities to present their ideas through writing, drawing, or thinking?			
- Do students have opportunities to present their ideas to other audiences? Ex) the class			
6. Discuss with learners the importance of modeling in science.			
- Are students encouraged to create models?			

- Do students understand what is a scientific model and how it helps them learn new information?			
- Do students practice modeling with their groups?			
- Do students create explanations using their models for reasoning?			

A total of ten fidelity sheets were completed over the five garden-inquiry lessons. For a total of 25 instructional days, the researcher taught each class for a fifty-five-minute period on Mondays, Tuesday, Wednesdays, and Fridays. Many of the lessons took more than one class period to complete. However, one fidelity worksheet was used per lesson rather than over each class period taught.

measures.

views about scientific inquiry - modified (VASI); *eight open-ended items (Lederman et al, 2014).*

This measure was created to better understand how students comprehend scientific inquiry and all aspects that align with inquiry (see Appendix E). Researchers created this instrument to investigate the *doing* and *understanding* of inquiry. One additional question was added to the original instrument for this dissertation. The extra question asked about scientific modeling. The general aspects of this instrument include: 1) questions to guide investigations, 2) multiple methods of scientific investigations, 3) inquiry procedures are guided by the question asked, 4) all scientists performing the same procedures may not get the same results, 5) inquiry procedures can influence results, 6) sources, roles of, and distinctions between scientific data and scientific evidence, 7) research conclusions must be consistent with data collected, and 8) how explanations and models are developed from a combination of collected data and what is already known. Scoring responses were based on what inquiry aspects could be found in each individual question. Scoring was completed in a hierarchy of 0 – 3; (0 - missing or no answer, 1 - naive surface level comprehension, 2 - mixed understanding, and 3 - deeper level understanding may use an example within the response) to distinguish the level of comprehension for each question. Therefore, each student will have a comprehension score for each individual VASI item (Schwartz, Lederman & Lederman, 2008). This instrument has been validated with teachers, pre-service teachers, and students (Lederman et al, 2014; Lederman, Lederman, & Antink, 2013; Schwartz & Lederman, 2008; Schwartz, Lederman & Lederman, 2008).

views about scientific inquiry interview - modified VASI; *eight open-ended items (Lederman et al, 2014; Schwartz, 2005).*

For the interviews, only 25% of the overall treatment group was asked to give pre-test and post-test questionnaire interviews. The researcher first read over the surveys and then reviewed the survey with the individual student. The researcher probed the interviewee about his/her written answer and asked him/her to elaborate or to explain why he/she wrote something in the response. This interview data was used to support what is said in the open-ended questionnaire. The interview allowed the researcher to have a more holistic understanding about a student's responses. The interview data is not necessarily scored but instead used as an extension and support of the written response. The interview response allowed the researcher to confirm that the written open-ended questionnaire items were scored correctly (Lederman et al, 2014; Schwartz, Lederman & Lederman, 2008).

scientific practices - Project 2061.

Eight multiple choice items were chosen from the Project 2061 assessment bank (AAAS, 1990). The items were under the content topic: Nature of Science. Within this topic, the subtopics, control of variables strategy (CVS) and modeling (see Appendix D) were chosen as content knowledge that can be measured. Though these items directly relate to the NOS, they can also be observed in inquiry practices and the understanding of scientific inquiry (Lederman et al, 2013;

Schwartz & Lederman, 2008). An individual must understand what variables to use and when to use them in order to conduct an investigation (Chen & Klahr, 1999). As with modeling, students must be able to demonstrate how they can create a model of a natural phenomenon or explain how a model can help their process in an investigation (Schwartz & Lederman, 2005). These items were specifically chosen because, throughout the garden intervention, the students were asked to demonstrate their understanding with different variables as well as to draw models for their garden and engineering challenges.

Consequently, across the eight items, some questions are more straightforward for students to interpret, such as the CVS item with a farmer and two different fields or the modeling item asking what components are needed for a model of a ship. Furthermore, the straightforward items were chosen because each item relates to earth or biological sciences. These questions were purposefully chosen due to the direct association between activities and processes to which the treatment group of students would be exposed during the intervention. This was done intentionally to help the students better understand what the items were asking. The researcher did not want to give items that would cause more cognitive load on the students' working memories. Rather, the researcher wanted the students to view items that they could find consistent with a direct transfer of knowledge.

These items were created with funding from the National Science Foundation and have been validated with over 1000 middle and high school students (AAAS, 2016). These answers were scored for correctness with a range from 0 – 1, with a maximum score of 8 for all answers being correct. Cohen's Kappa was calculated to determine how these eight questions worked together, even though the questions were created to be used in a mix and match fashion

Procedures

Pencil and paper assessment items were given to treatment group students prior to participation in school garden PjBL inquiry activities (*pre-test*) and following completion of school garden PjBL inquiry activities (*post-test*) (see Figure 3). In addition, 25% of students from both treatment group class periods were interviewed. The pre-test, post-test, and interviews occurred during the allotted science class period. The researcher administered the surveys to the classes and proctored the individual student interviews. The comparison group was only able to take the post-test survey. Due to circumstances beyond the control of the researcher, i.e., parent permission forms not being signed until late into the intervention and lack of instructional time given to the researcher, the comparison group was only given the assessment as a post-test survey rather than a pre-test and post-test survey.

data collection.

Pre-test and post-test data were collected through a paper-and-pencil survey before the first school garden inquiry lesson and after the last school garden inquiry lesson. After the pencil-and-paper pre-test, 25% of the students were also interviewed. Following the post-test written survey 50% of the students were interviewed after the last school garden inquiry lesson. The researcher collected field notes and made group observations during each school garden inquiry lesson. Pre-test and post-test measures were collected with the treatment group as planned. However, testing of the comparison group was limited to only one time point because the teacher of the comparison group allotted only one day of instructional time for the primary researcher to collect measures. Because of this limitation, the researcher only collected data with the comparison group class during the same week as collecting post-test results with the treatment group.

Table 5 below demonstrates how intervention lessons align with the eight aspects of scientific inquiry and the eight practices by NGSS.

Time	Delay	Items for Students to Complete
1	n/a	8 items Views About Scientific Inquiry
		8 items Scientific practices
2	Eights weeks after Time 1	8 items Views About Scientific Inquiry
		8 items Scientific practices

Figure 3. *Framework overview for study procedures and what items will be collected with students during the two different time points. Please note that 25% of the participants were also be interviewed at these time points.*

Table 5. *How Lessons Align with VASI Questionnaire, NGSS Practices, and Aspects of SI*

Lesson	Objective	VASI Item #	AAAS Item #	NGSS Practice(s)	Aspect(s) of SI
1	How to investigate world hunger.	1	NA	Asking questions. Planning and carrying out investigations. Obtaining, evaluating, and communicating information.	Scientific investigations all begin with a question but do not necessarily test a hypothesis. There is no single set or sequence of steps followed in all investigations. Inquiry procedures are guided by the question asked.
2.1	What is observation?	1	NA	Asking questions. Analyzing and interpreting data. Using mathematical thinking.	Scientific investigations all begin with a question but do not necessarily test a hypothesis. Inquiry procedures are guided by the question asked. All scientists performing the same procedures may not get the same results.
2.2	What is the difference between	1, 2, 3b	NA	Asking questions.	All scientists performing the same procedure may not get the same results.

	observation and inference?			Constructing an explanation. Analyzing and interpreting data.	Multiple methods for the same question. Different conclusions may be justifiable from the same set of data or information. Scientific data are not the same as scientific evidence.
3.1	How to plan an experiment? How do procedures affect results?	3a, 4	Control Variables Strategy	Planning and carrying out an investigation. Analyzing and interpreting data. Constructing explanations.	Inquiry procedures are guided by the question asked. Inquiry procedures can influence results. Scientific data are not the same as scientific evidence. Explanations are developed from a combination of collected data and what is already known.
3.2	Understanding types of data. Differences between quantitative and qualitative data. How are data and evidence different?	3b, 4	Control Variables Strategy	Analyzing and interpreting data. Constructing explanations. Obtaining, evaluating, and communicating information and using this information.	Scientific investigations all begin with a question and do not necessarily test a hypothesis. Inquiry procedures can influence results. Scientific data are not the same as scientific evidence. All scientists performing the same procedure may not get the same results. Research conclusions must be consistent with the data collected. Explanations are developed from a combination of collected data and what is already known.
4	Why do we plan our investigation first? How does evidence support your explanations?	6, 7	NA	Asking questions and defining problems. Planning and carrying out investigations. Obtaining, evaluating, and communicating information. Constructing explanations.	Scientific investigations all begin with a question and do not necessarily test a hypothesis. Inquiry procedures are guided by the question asked. All scientists performing the same procedure may not get the same results. Research conclusions must be consistent with the data collected. Explanations are developed from a combi-

					nation of collected data and what is already known.
5.1	Learning how to design.	5, 8	Modeling	Asking questions. Developing a model.	Scientific investigations all begin with a question and do not necessarily test a hypothesis. Inquiry procedures are guided by the question asked. There is no single set or sequence of steps followed in all investigations. All scientists performing the same procedure may not get the same results.
5.2	Evaluation of engineering design	8	Modeling	Developing a model. Engaging in argument from evidence. Constructing explanations and designing solutions. Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.	Inquiry procedures are guided by the question asked. All scientists performing the same procedure may not get the same results. Inquiry procedures can influence results or design. Explanations are developed from a combination of collected data and what is already known.
5.3	Construction of engineering design	8	Modeling	Developing a using a model. Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re- testing.	Inquiry procedures are guided by the question asked. Inquiry procedures can influence results. Explanations and models are developed from a combination of collected data and what is already known.

Analysis

During analysis, it became apparent that within the span of the school-garden intervention (eight weeks), two students had moved from the school district, and one student switched to another sixth-grade team. These absences are accounted for in all figures and tables. These absences should be taken into consideration when looking at the treatment group's post-test scores for both assessments.

qualitative analysis.

The researcher investigated whether participation in the school garden affected students' understanding and knowledge about scientific inquiry and practices by conducting qualitative analysis on post-test VASI items and interview items in addition to triangulating fieldnotes and photographs to support students' responses.

fidelity worksheets (inquiry analysis tool).

The researcher used triangulation between the fidelity worksheets and the student VASI responses to better understand what aspects could have been more explicitly discussed by the researcher during the intervention. A frequency table in Chapter 4 displays what was observed being discussed and taught throughout each lesson.

views about scientific inquiry – modified VASI*; eight open-ended items (Lederman et al, 2014; Schwartz, 2005).*

The eight items are open-ended responses. These responses were coded following a protocol coding process created by the original authors of the instrument (Lederman et al, 2014). Responses were analyzed to describe the degree to which responses were indicative of accurate conceptual understanding of scientific inquiry aspects. There was a total of four levels: Level 0 – missing data, Level 1 – an incorrect or naive surface level understanding; Level 2 – mixed understanding responses consistent with an accepted scientific inquiry aspect(s) but does not display meaningful comprehension over an inquiry aspect; and Level 3 – the correct response includes an explanation with an inquiry aspect(s) and demonstrates mature understanding of scientific investigations and scientific practices. This rubric assigned students a score for a comprehension rating for each VASI item (Lederman et al, 2014; Schwartz, Lederman & Lederman, 2008). There is not a specific one-to-one correspondence of VASI item to aspect found in SI. The researcher used the scoring rubric from the original paper to guide initial coding for targeted comprehension about scientific inquiry aspects (Lederman et al, 2014; Schwartz, Lederman, & Lederman, 2008). Table 6 below demonstrates how the eight aspects of NOSI align with the questions from the VASI instrument with the addition of Question 8 concerning models. Student written responses were first reviewed and coded with descriptors relating to the targeted aspect in scientific inquiry. After initial coding, a coding rubric was adapted from Lederman et al. (2014) (see Table 7), and once finalized, the researcher and another researcher used it to code the student responses. The student responses were coded independently from each other to establish interrater reliability (Miles & Huberman, 1994; Gwet, 2014). Interrater reliability was calculated using Cohen's kappa.

When coding differences arose between researchers, the codes were discussed until reaching agreement. This constant review of responses continued until researchers achieved an interrater reliability score of Kappas Cohen = .95 (Gwet, 2014).

Table 6. *Aspects of Scientific Inquiry (SI) and Corresponding Items on VASI Questionnaire*

Aspect of Scientific Inquiry	VASI Item #
1. Scientific investigations all begin with a question but do not necessarily test a hypothesis.	1a, 1b, 2
2. There is no single set and sequence of steps followed in all scientific investigations (i.e., there is no single scientific method).	1b, 1c
3. Inquiry procedures are guided by the question asked; questions drive the process.	5
4. All scientists performing the same procedures may not get the same conclusions.	3a
5. Inquiry procedures can influence the conclusions.	3b
6. Research conclusions must be consistent with the data collected.	6
7. Scientific data are not the same as scientific evidence.	4

8. Explanations and models are developed from a combination of collected data and what is already known.	7a, 7b, 8

Note. **Question 8 was taken from the Views On Scientific Inquiry (VOSI) and added to this student questionnaire for this dissertation.*

Table 7. *Rubric for Scoring the VASI Questionnaire (adapted from Lederman et al., 2014)*

Question Number and Inquiry Aspect	Informed	Mixed	Naive
1a, 1b and 1c. Scientific investigations can follow different methods	All three answers must be appropriate: 1a: Yes, the investigation is scientific as it aims to explain some aspect of the natural world 1b: No, it is not an experiment as there is no manipulation/control of variables/testing 1c: Yes, investigations can follow different method: experimental/practical/testing as opposed to non-experimental/research/investigation/observation/theoretical/not practical Two suitable examples required: one experimental and the other non-experimental	No more than one of the following types of mistakes: 1b: Yes, it is an experiment Or: 1c: both examples are experimental Or: 1c: both examples are non-experimental	1c: Only one scientific method Or: any two/more mistakes, e.g: 1b: Yes, experimental and 1c: similar examples

2. A scientific investigation should begin with a question, not necessarily a hypothesis	A question is the fundamental reason why an investigation is undertaken	A question is useful but is regarded as part of a formal structure Investigation may be undertaken first and questions formulated later	Investigations should start with a hypothesis; questions are not essential
3a. All scientists performing the same procedures may not get the same results	The human factor may cause different interpretations of similar data, leading to different results	Imperfect experimental conditions may lead to different results	Similar procedures would always lead to the same results/human error
3b. Procedures of investigations can influence results	Different procedures would yield different results/ different results can also lead to the same conclusion	Different results would be primarily caused by the different interpretations	Only one result is possible regardless of the procedure
4. Data are not the same scientific evidence	Evidence is generated from data, to support a claim/conclusion	Evidence differs from data; unclear/wrong/ no explanation	There is no difference between data and evidence
5. Questions drives the process	Team A did the best experiment because they addressed the proposed question	Team A did better, no explanation/argues that the tire has a larger effect than road	Team B did better, illogical or no explanation
6. Conclusions should be consistent with data collected	Option (b) is correct, i.e. ‘plants grow taller with less sunlight’ because the data showed such a trend Speculations about the ‘unusual’ data are acceptable provided option (b) is chosen	Option (c) is correct, i.e. ‘growth not related to sunlight’ with an explanation Or: option (b) without explaining	Option (a) is correct, with or without an explanation Or: option (c) with no or illogical explaining

7a and 7b. Explanations and models must be based on data and existing scientific knowledge	Three relevant ideas: Two reasons: function of larger hind legs/ comparison with existing models of dinosaurs/fitting of joints One information type: existing knowledge of dinosaurs/skeletons/ joints	Only two relevant ideas	One or no relevant ideas
8a, 8b, and example. Explanations and models must be based on data and existing scientific knowledge	Two relevant ideas: Models are a representation of an event, process, or object. Models assist in explaining and assist in creating new knowledge.	Only two relevant ideas, Or: only one relevant idea with one example	One relevant idea

interviews over the VASI.

These interviews produced descriptions of how students understand practices and what knowledge was created from the process of SI. Interview recordings for *Views About Scientific Inquiry - modified* were listened to before analysis. The interviews should demonstrate that the interview responses are parallel or similar to the written responses. Both the interview recordings and the open-ended responses were compared to one another to determine if any new themes arose out of the interview data.

Interviews were collected during both pre-test and post-test with the treatment groups and post-test with the comparison group. The researcher sat side-by-side with an individual student and probed the student about his/her responses to each VASI question. After reviewing the results of the interviews with another researcher, it was decided that the interviews could not be used for this dissertation. This decision was made because, when listening to the interviews, the VASI instrument was used more as a teaching tool then as a questionnaire. The researcher assumed that the students' ages and emotions influenced their responses as they were timid and shy in their responses. Almost all of the students looked to the researcher at the end of their responses for acknowledgment of correctness rather than understanding that the questions have no right or wrong answer. Sometimes the students would repeat what the researcher said rather than state their own thoughts about the written responses. Therefore, the student interviews were not included as a data source for this dissertation.

analysis of field notes and photographs.

The researcher conducted additional field observations throughout the unit, which included: group-level interactions, researcher-and-student interactions, and independent student interactions. From these observations the researcher wrote field notes. These field notes allowed the researcher to reflect on what occurred in the classroom that day and determine if any changes needed to be made for the next day's lesson. In addition, these field notes indicated where challenges or successes were occurring with the treatment group students. Along with these field notes, field photographs were taken throughout the intervention. These photographs were taken live while students and the researcher were participating in the school garden inquiry lessons. From these photographs, the researcher could reflect on what behaviors and practices the students were demonstrating. This allowed the researcher to have an in-the-moment record of what students were actually experiencing throughout the intervention. Furthermore, photographs could display if students were performing the correct practice during specific lesson activities.

Students also had field notebooks throughout the unit. In the field notebooks students responded to open-ended questions and worksheets. In addition, each group of students was given butcher paper to sketch out and write out ideas.

All forms of data allowed the researcher to better understand how students were developing an understanding about scientific inquiry, what kind of knowledge they learned, and what practices they gained from the garden inquiry unit. The researcher was able to triangulate individual student data (VASI open-ended, interviews, and quantitative science practice items) with group data (worksheets and sketches/designs on butcher paper).

quantitative analysis.

scientific practices – Project 2061.

The researcher investigated whether participation in the school garden affected students' scientific practices by conducting a quantitative analysis of pre-test and post-test responses to the eight Project 2061 items.

A paired samples t-test was used to analyze pre-test and post-test scores within the treatment group (Boneau, 1960). Effect size was also calculated to better understand the magnitude of impact over the students who participated in the intervention (Fern & Monroe, 1996; Fritz, Morris, & Richler, 2011). Cohen's *d* is the appropriate effect size measure because the two groups have similar standard deviations and similar size.

An independent samples t-test was used to analyze post-test scores between the two different groups, treatment and comparison (Feir-Walsh, & Toothaker, 1974). Again, Cohen's *d* effect size was also calculated between the two different groups to find a better representation of how the intervention impacted each group (treatment versus comparison), without the challenge of sample size (Fern & Monroe, 1996; Fritz, Morris, & Richler, 2011).

Reaseacher Positionality

The researcher first began cultivating a relationship with the school site in spring 2014 through a local nonprofit. This nonprofit is interested in curriculum-based, informal education in school gardens. Through this school garden-centric nonprofit, the researcher was also recruited to work with another local nonprofit whose interests are in forestry and urban environmentalism education. Belonging to these nonprofits has given the researcher several fundamental opportunities of interaction between schools, teachers, students, parents, administration, and the private sector. By working with these nonprofits, the researcher has gained key skills in communicating between these groups and understanding how the research relates to each group differently. Working within these spaces allowed the researcher to explore how current out-of-classroom education is taught and incorporated within the public-school system. Furthermore, by having experience-creating curricula and working within the classrooms alongside teachers, the researcher had a unique perspective to observe whether the proposed work was successful completed by the students. In addition, the researcher had the advantage to ask teachers and students for their views and ideas about why parts of the intervention may have failed.

In relation to the overall study, the researcher was the primary investigator, but to the school site, the researcher was seen as a doctoral candidate investigating how students develop scientific practices in science class. Over time, the researcher built positive relationships with the following groups at the school site: teachers, administration, students, and the science coach. Due to the length of time working with the school site and continuation of similar science projects, the researcher was perceived to be more a part of the school staff rather than an outsider.

For this study, the researcher constructed her position from the domain of science and race (St. Louis & Barton, 2002); as a Colombian-American woman pursing a PhD, positioning herself as emic to her work for several reasons. The researcher took the time to build a relationship with the school site and all groups with which she has interacted. This process included working with one of the after-school clubs while also maintaining close communications with the science coach. The researcher came from the sciences as both her undergraduate and graduate degrees are in the ecological sciences. This background assures teachers, students, and administration that the researcher was knowledgeable in the classrooms where teaching. By working with nonprofits, the researcher has assisted in creating and evaluating educational interventions, which demonstrated how she had created, implemented, and evaluated new curriculum. These experiences allowed her to create a unique insider perspective with her school site.

Throughout the research process, the roles of positionality have assisted the researcher's overall work. As a minority female interested in science learning, the groups at the school site readily accepted her. This insider relationship allowed her to work closely with participants in all phases of research – data collection, analysis, and reporting findings. In addition, by having previously worked with nonprofits on informal education interventions she came into the investigation with the knowledge of how to manage unforeseen challenges.

Overall, by keeping constructivist paradigms and situated learning theory, the researcher realized how her positionality and subjectivities may affect the investigation and the process of research. The constructivist paradigm allowed her to investigate not only how the teacher and student learn from the intervention but also how she constructed understanding after watching the student-to-student and student-to-teacher interactions during the intervention. Mindful of this, the researcher realized that her investigation permitted her to work with students and teachers while allowing her to explore how situated informal education curriculum affected students' views on scientific inquiry and their understanding about scientific practices. This research will benefit not only the researcher and the field of science education but also the entire school site and the field of informal education research.

4 RESULTS

The results are organized by research question. The research conducted for this dissertation was mixed-methods because the multi-faceted approach was needed to answer the two primary research questions. In addition, the research questions were answered in two ways, a comparison between the pre-test and post-test survey of the treatment group, students in the garden intervention; and a post-test survey comparison between the treatment group and the comparison group. The research questions are:

1). How does participating in the school garden inquiry unit affect students' understanding about science inquiry?

2). How does participating in the school garden inquiry unit affect students' scientific practices?

Research Question One is answered using a more qualitative approach by implementing the Views About Scientific Inquiry (VASI) instrument (Lederman et al, 2014). Research Question Two is answered using a more quantitative approach by implementing eight multiple choice items from Project2061 (AAAS, 1993). The VASI items align with the eight Nature Of Scientific Inquiry (NOSI) aspects and focus on the process of scientific inquiry and knowledge gained from this process, while the Project2061 questions are more content driven and focus on the application of knowledge about scientific inquiry in the form of a science practice. In addition, the researcher added photographs of the students during the intervention. These photographs demonstrated how the students were engaged with different Next Generation Science Standards (NGSS) practices throughout each lesson. The photographs also demonstrated how the students were fully immersed and were actually experiencing each NGSS practices. During the intervention, the comparison group received sixth-grade science instruction based on the Georgia Standards of Excellence and Next Generation Science Standards. The treatment group participated in the school-garden intervention.

Fidelity worksheets (Inquiry Analysis Tool)

As explained in Chapter 3, Methodology, an inquiry tool was modified and used to observe the researcher when she taught the five garden inquiry lessons. Table 8 below displays the frequency count of observed teaching practices by the researcher across all five lessons.

Table 8. *Displays the cumulative frequencies of observed teaching practices by the researcher*

Does the material/lesson:	Yes	No	N/A
1. Engage learners in scientifically oriented questions?			
- Do questions guide inquiry?	10		
- Are questions relevant to students?	10		
- Do students understand that investigations start with a guiding question?	10		
2. Ask learners to give priority to data/evidence?			
- Do students understand the difference between data and evidence?	8		2
- Do students use their senses and instruments to collect data?	10		
- Are students taught that different individuals can collect different data due to different methodologies?	8		2
- Do students evaluate the data they are gathering?	8	1	1
3. Encourage learners to create and design investigations from research?			
- Are students encouraged to design their own investigations?	5	1	4
	6	1	3
- Do students base their investigations from research?	4	1	5
- Are students asked to explain their reasoning for the design of their investigation?	5	1	4
- Do students plan and organize their investigations?			
4. Discuss with learners subjectiveness and tentativeness of science?			
- Do students understand that each group may have different procedures and conclusions?	8		2
- Do students understand that creativity and imagination are used in science?	5	4	1
- Do students understand that science can change due to new discoveries and technology?	5	3	2
5. Expect learners to communicate and justify			

their proposed designs, investigations, and explanations?			
- Do students have opportunities to discuss their ideas in small groups?	10		
- Do students have opportunities to present their ideas through writing, drawing, or thinking?	9		1
- Do students have opportunities to present their ideas to other audiences? Ex) the class	7		3
6. Discuss with learners the importance of modeling in science.			
- Are students encouraged to create models?	4	2	4
- Do students understand what is a scientific model and how it helps them learn new information?	3	5	2
- Do students practice modeling with their groups?	2	3	5
- Do students create explanations using their models for reasoning?	3	2	5

Across the six areas being evaluated, the most problematic area for the researcher was Area 4, the subjectiveness and tentativeness of science, see Table 8. In three lessons, the fidelity worksheets indicated that these topics were not explicitly connected with the lesson. The second area in which the researcher did not necessarily explain in depth to the students was the importance of modeling and how modeling is used in the field of science. Comments on the fidelity worksheets note that the researcher demonstrated and discussed modeling, but only in the context of the lesson, not in a larger context of how scientists and engineers use modeling. Overall, the other four areas were explicitly discussed with students during the five garden-inquiry lessons. In addition, the researcher helped students reflect on how the lessons related to what professionals do in their fields. The four areas that were successfully completed across all lessons were: 1. Engage learners in scientifically oriented questions; 2. Ask learners to give priority to data/evidence; 3. Encourage learners to create and design investigations from research; and 5. Expect learners to communicate and justify their proposed designs, investigations, and explanations. Appendix E contains all ten fidelity worksheets across all five lessons to see how the primary researcher was evaluated using the *Inquiry Analysis Tool* (Volkmann & Abell, 2003).

Research Questions and Measures

To reiterate, each research question was answered two ways: treatment group responses pre-test compared to post-test, as well as, treatment group post-test compared to comparison group post-test. Therefore, each research question was subdivided into two sections of findings.

research question 1 and the VASI instrument.

The first research questions asked, "How does participating in the school garden inquiry unit affect students' knowledge and understanding about science inquiry?" The following section describes how students responded to the VASI instrument, with student quotes presenting responses from students pre- and post-intervention views. Participants' views of each target NOSI aspect are presented separately. Also, it should be explained that while some participants' quotes are presented as naive (or informed) views of one NOSI aspect, the same quote might equally serve as evidence as naive (or informed) views of another target aspect. Nevertheless, it should be understood that participants' views are not always well thought out and sophisticated across all eight aspects. Instead, the participants' views may appear to be inconsistent across the aspects. For example, some participants explained informed views of the data and evidence aspect, but not of the question guides of the procedures aspect. Interrater reliability was calculated using Cohen's kappa (*K)* between the researcher and another researcher, the researchers' interrater reliability was calculated to be 0.95. Disagreements were resolved with discussion. Once kappa was calculated, the primary researcher continued to classify the responses into the three categories: naive, mixed, and informed. In addition, photographs demonstrating student engagement with a NOSI aspect were also found in this section. These photographs were taken by the researcher while the students were participating in the intervention. Furthermore, graphs were created as a visual representation of the student responses across the three categories: naive, mixed, and informed. These graphs are organized by treatment group or comparison group as well as whether the responses are from the pre-test or the post-test. All graphs can be found in Appendix G.

In the following sections, participant quotes are identified by letters and whether the response was pre- or post-intervention. The letters “T” and “C” are used to identify participants in the treatment and comparison group, respectively. The quotes also indicate what level of understanding that a student holds: naive, mixed, or informed. Due to the number of participants, only specific example quotes are embedded within each explanation of NOSI aspect. However, more example quotes from each group can be found in Appendix H.

there is no single set and sequence of steps followed in all scientific investigations (i.e., there is no single scientific method).

Question 1 assessed student understanding about scientific investigations – specifically that scientific investigations can follow different methods, i.e., there is no one scientific method, see Figure 2. The question is divided into three sub-questions. Part (a) evaluates whether students understand what the word “scientific” means. Part (b) evaluates whether students understand what an “experiment” is. And Part (c) evaluates whether students understand that there are various methods of investigating.

treatment pre-test compared to treatment post-test.

For this question, the most common naive responses claimed that the bird investigation was an experiment and that there is only one way to conduct an investigation or an experiment.

Treatment pre-test responses were predominantly naive before the intervention (naive 58.8%, mixed 35.3%, informed 3.9%). Furthermore, after coding, it became more obvious that many students did not necessarily understand what an experiment is. Many described a type of investigation or type of data collection as an experiment. They did not display the knowledge that an observation can also be a type of investigation, see Appendix G.

> *Yes, because he had a guess that maybe the shape of the bird's beak was related to the type of food.*
> *Yes, because anything can be an experiment if there is a data to collect or something to test.*
> *Yes, one investigation is fossils, one person digs up the fossils and the other analyses it and puts it together.*
> (T, pre-intervention, naive view)

However, after the intervention, the treatment group post-test responses changed dramatically (naive 35.3%, mixed 37.3%, and informed 19.6%). Majority of the students now held a more mixed or informed view.

> *Yes, because he observed the birds just using his 5 senses. Observation uses the five senses for scientific investigations.*
> *This is not an experiment because this person isn't testing anything.*
> *Two investigations are observations and experiments. Observation means to observe, but experiment means to test it out.* (T, post-intervention, informed view)

treatment post-test compared to comparison post-test.

The comparison group did not do well on this question (naive 65.4%, mixed 30.8%, informed 3.8%). Over half held naive views with very few students holding informed views. The treatment group post-test responses (naive 35.3%, mixed 37.3%, and informed 19.6%) held many more informed views than the comparison group at this point in time in the semester. In actuality, the treatment group pre-test responses (naive 58.8%, mixed 35.3%, informed 3.9%) are more similar to comparison group responses.

> *Yes, because he made a hypothesis.*
> *Yes, because he used different types of birds that eat the same types of foods and tested them to see their beaks. One investigation that follows a different method is to replicate; another one is to change an independent variable.* (C, no intervention, naive view)

> *This person's investigation is scientific because he collected data about birds.*
> *No, because he does not test anything.*
> *Yes, investigations can follow more than one method because you could find the same answer with different procedures.* (T, post-intervention, informed view)

The most salient theme across both groups was the claim about the scientific method or hypothesis testing. This theme appeared as: treatment pre-test (19.6%), treatment post-test (6%), and comparison post-test (34.6%), indicating that some students view that there is only one way to conduct an investigation or that an investigation must always begin with a hypothesis, see Appendix H.

scientific investigation starts with a question but not necessarily a hypothesis.

Question 2 assessed whether an individual understands that a scientific investigation starts with a question but not necessarily a hypothesis. Students answered with a “yes” or “no” and were asked to provide reasoning for their answer.

treatment pre-test compared to treatment post-test.

On the pre-test, the majority of the treatment group students responded with a mixed understanding (58.8%) and informed responses (19.6%), see Appendix G.

> *Yes, because the only way the investigation can be created is by asking a question*. (T, pre-intervention, mixed view)

These responses demonstrated that more than half of the treatment group students knew that a question drives an investigation before the intervention took place. For the naive responses (17.6%), students indicated that investigations do not need to start from a question.

> *No, because not all scientific investigations always begin with a scientific question.* (T, pre-intervention, naive view)

After the intervention, the treatment group responses were mixed (45.1%) and informed (31.4%), which indicated that students understood how a question drives the scientific inquiry process. Only (15.7%) of students in the treatment group responded with a naive response after the intervention.

> *Yes, you need a question because you need a reason for your investigation. Can't be out of the blue. The question guides what you're doing*. (T, post-intervention, informed view)

treatment posttest compared to comparison posttest.

For the comparison group, the majority of these students fell into the naive response category (50%); the remaining students responded that they were aware that a question must be posed before an investigation can begin (34.6% mixed and 15.4% informed).

> *I agree with the first student because a scientific question is the base of an experiment.* (C, no intervention, naive view)

> *I agree with the one that says yes, because if you don't start with a guiding question how are you going to know what to investigate or what to experiment.* (T, post-intervention, informed view)

When comparing the treatment group post-test responses (naive 15.7%, mixed 45.1%, informed 31.4%) to the comparison group post-test responses (naive 50%, mixed 34.6%, informed 15.4%) the treatment group has far more responses in the mixed and informed categories than the comparison group, see Appendix G.

In addition, it was noted that both the treatment group pre-test (5.9%) and the comparison pre-test group (15.4%) answers discuss the use of the scientific method or hypothesis testing. Treatment group post-test responses show that only (4%) mention the use of the scientific method or hypothesis testing.

all scientists performing the same procedures may not get the same conclusions.

Question 3a assesses the understanding that scientists may come to different conclusions even when performing the same procedures due to different interpretations of results which can lead to different conclusions. Scientists have different experiences, prior knowledge, and different epistemological beliefs that can affect their interpretation of results and lead to conclusions that differ. Student responses categorized as naive or mixed do not acknowledge how individuals' different backgrounds, experiences of life, and prior knowledge can shape conclusions.

treatment pre-test compared to treatment post-test.

In the treatment group, naive responses indicated that similar procedures would lead to the same conclusions. Before the intervention, pre-test views were mostly naive (66.7%) following with mixed (19.6%), and informed (11.8%), see Appendix G.

> *I think no because one person can do something wrong while the others can have correct answers/conclusions.* (T, pre-intervention, naive view)

After the intervention, the treatment group did see some change in their views. During post-test, naive dropped to 43.1%, mixed views increased to 27.5%, and there was some change in informed views as well 21.6%. This was an abstract aspect but the many of the students were able to change their views, see Appendix G.

> *I cannot say for sure because some may have the same conclusions while others might have different conclusions because we think differently*. (T, post-intervention, informed view)

treatment post-test compared to comparison post-test.

The comparison group did not do particularly well with this question. The majority of student responses were categorized as naive (69.2%). In both categories, mixed (15.4%) and informed (15.4%) of the comparison group had a few students holding this view, see Appendix G.

They will come to the same conclusions because they did the same procedures and the same questions. (C, no intervention, naive view)

No because if scientist have the same data one scientists may comprehend better than the other then they might say something different. (T, post-intervention, informed view)

Unlike the treatment group, post-test responses were naive (43%), mixed (27.5%), and informed (21.6%), which demonstrate more student understanding when compared to the comparison group post-test, see Appendix G. The comparison groups' responses appear more similar to the treatment group responses before the intervention.

A theme that was identified throughout the naive responses is the notion of human error or mistake: treatment group pre-test (19.6%), treatment post-test (16%) and comparison group post-test (19.2%). This indicates that students did not completely understand how *human* interpretation plays a role in conclusions. Apparently, many students view science as being objective and do not understand how human bias may play a role in science.

inquiry procedures can influence the conclusions.

Question 3b focuses on how procedures to investigate a question can influence the results. Ideally, students should understand that different procedures can yield different results and generate different conclusions. Also, different procedures may also yield similar results. Students need to realize that procedures influence the overall conclusion of an investigation.

treatment pre-test compared to treatment post-test.

The treatment group's responses did not change significantly between the pre-test and the post-test, see Appendix G. In the treatment pre-test the students held naive views (31.4%) and then again at post-test (25.5%) meaning that many students believe in a single correct answer to a question.

Yes, they will get the same data. (T, pre-intervention, naive view)

Yes, they will have the same conclusion they both looked up the same thing. (T, post-intervention, naive view)

Little change was identified in either category in the treatment group: mixed (pre-test mixed 47.1%, post-test mixed 49%) and informed (pre-test 17.6%, post-test 17.6%). The mixed and informed views were the highest at post-test, which indicates that students do realize that results can be shaped and changed by the design of an investigation, see Appendix H.

No, because their method of doing things can be different, which will make their conclusion different. (T, post-intervention, informed view)

They will not come to the same conclusions because scientist follow their own procedures. (T, post-intervention, mixed view)

The theme that was identified most in the post-test of the treatment group was the relation to mathematics or the idea that there are several ways to solve a problem (7.8%).

They can get the same conclusions still. It is like math, 2+2=4 or 3+1=4. (T, post-intervention, mixed view)

treatment post-test compared to comparison post-test.

The comparison group (naive 46.2%, mixed 38.5%, and informed 3.8%) however, does worse when related to the treatment group post-test views (naive 25.5%, mixed 49%, and informed 17.6%), see Appendix H. Many of the comparison group students did not give explanations to explain their answers. This lack of explanation may indicate that their current or previous science teachers have not discussed this idea with them at school.

No because they have different procedures. (C, no intervention, naive view)

Yes if they do everything the same and correctly with no errors. (C, no intervention, naive view)

scientific data are not the same as scientific evidence.

Question 4 assesses the understanding that evidence differs from data. "Data" is information collected during scientific investigations; while, "evidence" is the result of interpretation or analysis of the "data".

treatment pre-test compared to treatment post-test.

A naive response indicates that the student believes that both terms are the same. At the time of pre-test, more than half (62.7%) of the students in the treatment group were categorized as naive.

> *No, because they both mean the same thing.* (T, pre-intervention, naive view)

A mixed response indicates that the student understands that the terms are different but cannot explain why. Across all groups, mixed responses were similar: pre-test (25.5%), post-test (29.4%), and comparison (30.8%), see Appendix G.

> *Data is information on a specific subject. Evidence is information that claims if something is try or not.* (T, pre-intervention, mixed view)

An informed response indicates that the student understands that the terms are different and can explain how human interpretation of data creates evidence. Informed responses for the treatment group at pre-test were 9.8%.

> *Data is information that is gathered. Evidence is information that supports a claim.* (T, pre-intervention, informed view)

By post-test, naive responses within the treatment group declined to 29.4%, indicating that students were more informed about this aspect of scientific inquiry after the intervention. In addition, after the intervention, treatment group post-test views in the mixed category (29.4%) and informed (33.3%) categories increased from pre-test to post-test, see Appendix G.

> *Data is information that you collected from your experiment. Evidence is analyzed and interpreted data from your experiment.* (T, post-intervention, mixed view)

> *Data is information that you collected from your experiment. Evidence is analyzed and interpreted data from your experiment.* (T, post-intervention, informed view)

treatment post-test compared to comparison post-test.

The comparison group post-test responses indicate a majority categorized as naive (57.7%), with mixed (30.8%) responses following, and informed (11.5%) responses as the category with the lowest number of responses, see Appendix G.

> *Data is something you know, evidence is how you know.* (C, no intervention, naive view)

> *Yes because data is what you collect and evidence is what you find about the data.* (C, no intervention, mixed view)

In reality, when looking at the percentages between the treatment group post-test and the comparison group post-tests they are not similar, see Appendix G. Instead, as seen in with previous items on the VASI, the comparison groups' responses are actually quite similar to the treatment group pre-test responses.

A continuous theme identified across the two groups is the connection that evidence is related to a crime or detective television show: treatment group pre-test (3.9%), treatment group post-test (2%), and comparison group post-test (7.7%).

inquiry procedures are guided by the question asked; questions drive the process.

Question 5 explores the aspect of how a question guides the investigation's procedures. Students are presented with a vignette in which two teams with differing procedures are trying to answer a question: hypothetical Team A's approach was most likely to answer the investigative question; while Team B's approach was unlikely to answer the investigative question. Students must determine which team and its procedures could best answer the question.

treatment pre-test compared to treatment post-test.

Within the treatment group responses, a naive response indicates an inability to determine which team and its procedures align with the presented question and why the procedures create a path to answering the given question. At the time of the pre-test, the measured results showed that 47.1% of the treatment group's responses were naive.

> *Team B because tests how a tire would react to a different surfaces of road.* (T, pre-intervention, naive view)

Students who could identify that one of the hypothetical team's (Team A's) approach was aligned but could not explain the reasoning for the alignment were categorized as mixed. At pre-test, the treatment group held mixed views (37.3%).

> *Team A is better because they are testing different tires on one type of road. This team is going to give a variety of answers.* (T, pre-intervention, mixed view)

For a response to be categorized as informed, students must explicitly discuss how Team A's procedures align with the proposed question. In this category the treatment group at pre-test informed views (11.8%).

> *Team A because they tested the tires and that was the original question.* (T, pre-intervention, informed view)

After the intervention the treatment group's responses showed change. Naive views dropped to 29.4%, mixed views increased to 49%, and informed views increased to 25.5%, indicating that across all categories learning occurred for the treatment group, see Appendix G.

> *Team A, their procedures were the best because their guiding question wasn't 'Do certain types of roads make tires more flat'? Team B did not follow the guiding question*. (T, post-intervention, informed view)

treatment post-test compared to comparison post-test.

At first glance, the majority of the comparison group's responses fall within the naive (57.6%) category, indicating an inability to determine which team and procedures align with the presented question and why the procedures create a path to answering the given question.

> *Team B's procedure is better because when you're driving you never know what type of road surfaces you could be driving on. (*C, no intervention, naive view)

> *Team B, because when you test more subjects you are closer to getting to an answer. (*C, no intervention, naive view)

> *Team A, because they're question is testing various tires, not various roads*. (T, post-intervention, informed view)

> *Team A is better because they follow the question.* (T, post-intervention, informed view)

Students in the comparison group did have some responses in the mixed category (34.6%) and some students were identified as holding informed (7.7%) views. For the most part, however, there was a large difference between the treatment group post-test responses and the comparison group post-test responses, see Appendix G.

research conclusions must be consistent with the data collected.

Question 6 required students to understand that data collected must be consistent with conclusions. Students were given a table with a data set about plants. This data set intentionally contradicted existing knowledge about photosynthesis and how plants grow, i.e., the data showed that less light was required for the plants to grow. Students needed to understand that data must always support given conclusions. Students were given three conclusions and are asked to select the conclusion they agreed with and to explain why they made their selection.

treatment pre-test compared to treatment post-test.

The breakdown of the pre-test treatment group's responses was: 29.4% naive; 19.6% mixed; and 50% informed. At time of the pre-test, more than half of the students were found to have a mixed or informed view.

> *A, because it is getting left out in the sun.* (T, pre-intervention, naive view)
>
> *B, if you look at the chart 25 minutes of sunlight the plant will grow 0cm but if you look at the 0 min of sun-light the plant will grow 25cm per week.* (T, pre-intervention, informed view)

By post-test, the treatment group responses shifted towards a more informed perspective majority; the breakdown of the responses were: 5.9% naive, 13.7% mixed, and 72.5% informed, see Appendix G.

B, because in the chart 25 minutes of sunlight results in no growth at all, but 0 minutes of light resulted in the highest growth. (T, post-intervention, informed view)

B, plants grow taller with less sunlight. My reason for choosing B is because it is shown on the graph that the plants are growing taller with less sunlight. (T, post-intervention, informed view)

treatment post-test compared to comparison post-test.

The comparison group results are as follows: (naive 23.1%, mixed 26.9%, and informed 50%). The comparison did do well on this question. The majority of students in this group held informed or mixed views. These results are similar to the treatment group's post-tests (naive 5.9%, mixed 13.7%, and informed 72.5%, see Appendix G. But as demonstrated in the other VASI items, the comparison group's post-test responses are more similar to the treatment group's pretest responses.

B, because the plant grew more inches than the less sunlight. (C, no intervention)

B, because in the data table 0 minutes of light and the plant grew 25cm per week. (C, no intervention, informed view)

The students who were categorized as naive ignored the given data and instead said that taller plants need more sunlight because this is based on their prior knowledge and experience with plants. Students may choose the wrong answer because they have learned that plants need sunlight to survive rather than thoroughly reading the question and understanding how the data collected informs their answer.

A, because the plant needs more sunlight for energy, growth and health. (C, no intervention, naive view)

A, sunlight is energy and soil. (C, no intervention, naive view)

explanations are developed from a combination of collected data and what is already known.

Question 7 probes students' understanding that explanations and models are created by a combination of data and existing scientific knowledge. This question presents students with two pictures of possible reconstructions of a fossilized dinosaur skeleton. The first sub-question asks students to explain why one reconstruction is better or more plausible than the other. The second sub-question asks students what kind of information would support their answer to the first sub-question. In the first sub-question, a naive response would focus only on the physiology of the bones, i.e., strong legs, balance, or current media views on dinosaurs. Few responses discussed fitting of joints or existing scientific knowledge about dinosaurs. When answering the second sub-question, students did not appear to fully understand what was meant by "types" of information. Many responses discussed modern media such as internet, textbooks, or search engines as a way that scientists create knowledge.

treatment pre-test compared to treatment post-test.

This aspect of scientific inquiry was not well understood with the majority of responses at the time of pre-test demonstrating a naive view (51%). Some students did demonstrate mixed views (29.4%). And some student responses were categorized as holding an informed view (17.6%) at time of pre-test.

> *I think scientists agree because it makes sense. The big bones on bottom and small bones on top. I think scientist can use tapes or making hypothesis or use the internet.* (T, pre-intervention, naive view)

> *This dinosaur looks like a t-rex. A t-rex has short legs in the front and the big legs in the back. The scientists use their own knowledge and the scientific method.* (T, pre-intervention, naive view)

However, by the end of the intervention, only a slight change was found in the treatment group's responses at post-test. By post-test, naive views had dropped slightly to 43.1%, a slight increase in mixed views (37.3%), and surprisingly, the informed views dropped to 11.8%, see Appendix G.

> *No dinosaur has short legs and big arms, but they do have small arms and big legs OR both arms and legs are the same size. They can use data from the people before us.* (T, post-intervention, informed view)
>
> *Because Figure 1 is standing and harder to fall. Figure 2 is bending and it has small feet, making it harder to carry the body so it can fall easily. Their hypothesis. Do more research and collect more data.* (T, post-intervention, informed view)

The theme of media as a source of information occurred in 26.6% of pre-test treatment group responses and 20% of post-test treatment groups responses.

> *1. The arms are in the wrong place. 2. The legs are in the wrong place. Movies. Internet. Encyclopedia. TV Shows.* (T, post-intervention)

treatment post-test compared to comparison post-test.

At the time of post-test, it appears that the comparison group had difficulty with this question. The majority of the comparison group's responses were naive (65.4%), followed by mixed views (30.8%). Consequently, none (0%) of the comparison groups responses were informed.

> *The dinosaur looks correct. They could've researched what the dinosaur should look like. Data and Hypotheses.* (C, no intervention, naive view)
>
> A T-Rex has short arms and big legs. It's also never slow down. They use research and dig up fossils to predict what they look like. (C, no intervention, mixed view)

The treatment group's post-test responses (naive 43.1%, mixed 37.3%, and informed 11.8%) were better than the comparison group's responses but not significantly, see Appendix H.

As found with the treatment group, within the comparison group's responses the theme of media as a source of information was found in 11.5% of the comparison group responses. In the responses mentioning media, the students described how a scientist could use the internet or textbooks to help find data and answers to investigative questions. The irony is that students are not realizing that scientists create the knowledge that is found in media.

explanations and models are developed from a combination of collected data and what is already known.

Question 8 is an adapted question from the View On Scientific Inquiry (VOSI) instrument (Schwartz et al, 2002) which can be used to better understand how models are a type of aide to help scientists explain a process, event, or object. An important abstract concept is that models do not have to represent the concept or object exactly. A naive response describes models as a simple visual representation of the process, event, or object. The majority of students discussed whether models are exact versions of what is being represented.

treatment pre-test compared to treatment post-test.

The majority of students in the treatment group at pre-test fell into the naive (72.5%) or mixed category (19.6%). These students could not explain that a model can be more than a perfect visual representation. Informed responses were extremely rare; only 3.9% of the pre-test treatment group responses were informed.

> *Basically like a 3D version of their thinking. They use it to experiment and basically showcase their ideas. A bridge made of popsicle sticks.* (T, pre-intervention, naïve view)

> *A model to demonstrate something they are making on is made in little form. To see how something is made before they make the real version or a better version. A model of soil layers.* (T, pre-intervention, mixed view)

By post-test, the treatment group students demonstrated a better understanding of modeling and how models can support explanations. At the time of post-test, the treatment group responses had decreased in the naive category (31.4%) and increased in both categories mixed (49%) and informed (11.8%), see Appendix G.

> *Something that shows an event, object, or process. They make models of objects and use observations or experiments to collect data from the model. Water cycle diagram.* (T, post-intervention, informed view)
>
> *A smaller version or a prototype of a larger version that can be tested. Scientist use scientific models by testing their procedures and the models to represent the big actual thing or different variable. Once they think they have the right model they use it to create the real thing. There is a solar system model in my room.* (T, post-intervention, informed view)

Note, 25.5% of the treatment group students were able to relate modeling to engineering and to understand how modeling is an iterative process where changes can be made throughout the process on their post-tests.

treatment post-test compared to comparison post-test.

The comparison group's post-test responses were predominantly naive (53.8%), with many students relating a model as a visual aid. There were many mixed category responses (42.3%). But, as with the naive responses, students are not understanding the concept that a model does not need to look exactly like what it is representing.

> *A model shows scientific evidence. To determine the answer to a question. A graph about something*. (C, no intervention, naïve view)
>
> *Prototype to show what the final product is going to be like. To show something they can't get to solve a problem. The solar system.* (C, no intervention, mixed view)

> *Basically like a mini presentation of the real thing and it explains the different features. They use them to explain what they've done. A scientific model is like a 3D figure like a presentation. Like one of those body statutes with one half showing the inside of the body*. (T, post-intervention, mixed view)

> *A mini version of a project that is needed to be done and the specific things that have to work on the bigger project. They use it for so many things like for people who make the golden gate bridge had to make so many models to make sure it's safe for all people. Our mini gardens in the classroom, that we did about the different types of soil is best.* (T, post-intervention, mixed view)

There were zero informed responses in the comparison group, see Appendix G. The concept of modeling and how modeling is connected to collected data and existing scientific knowledge appears to be a difficult aspect for many students to comprehend.

The following table below, Table 9, presents the percentages of student responses in each of the categories before and after the school garden inquiry intervention for both the treatment (T pre-test and T post-test) and comparison (C post-test) groups.

Table 9. *Percentage of Students Categorized as Holding Naive, Mixed, and Informed Views across Eight Aspects of SI in both treatment (pre-test and post-test) and comparison (post-test) groups.*

VASI #	Aspect #	Naive	Mixed	Informed	Missing
1a, 1b, 1c	2	Pre 58.8 Post 35.3 Comparison 65.4	Pre 35.3 Post 37.3 Comparison 30.8	Pre 3.9 Post 19.6 Comparison 3.0	Pre 2 Post .8 Comparison 0
2	1	Pre 17.6 Post 15.7 Comparison 50	Pre 58.8 Post 45.1 Comparison 34.6	Pre 19.6 Post 31.4 Comparison 15.4	Pre 3.9 Post 7.8 Comparison 0
3a	4	Pre 66.7 Post 43.1 Comparison 69.2	Pre 19.6 Post 27.5 Comparison 15.4	Pre 11.8 Post 21.6 Comparison 15.4	Pre 2 Post 7.8 Comparison 0
3b	5	Pre 31.4 Post 25.5 Comparison 46.2	Pre 47.1 Post 49 Comparison 38.5	Pre 17.6 Post 17.6 Comparison 3.8	Pre 3.9 Post 7.8 Comparison 11.5
4	7	Pre 62.7 Post 29.4 Comparison 57.7	Pre 25.5 Post 29.4 Comparison 30.8	Pre 9.8 Post 33.3 Comparison 11.5	Pre 2 Post 7.8 Comparison 0
5	3	Pre 47.1 Post 17.6 Comparison 57.6	Pre 37.3 Post 49 Comparison 34.6	Pre 11.8 Post 25.5 Comparison 7.7	Pre 3.9 Post 7.8 Comparison 0

6	6	Pre 29.4 Post 5.9 Comparison 23.1	Pre 19.6 Post 13.7 Comparison 26.9	Pre 49 Post 72.5 Comparison 50	Pre 2 Post 7.8 Comparison 0
7a, 7b	8	Pre 51 Post 43.1 Comparison 65.4	Pre 29.4 Post 37.3 Comparison 30.8	Pre 17.6 Post 11.8 Comparison 0	Pre 2 Post 7.8 Comparison 3.8
8a, 8b	8	Pre 72.5 Post 31.4 Comparison 53.8	Pre 19.6 Post 49 Comparison 42.3	Pre 3.9 Post 11.8 Comparison 0	Pre 3.9 Post 7.8 Comparison 0

Frequency counts were calculated for each category of student responses between both the treatment and comparison groups. However due to space limitations all frequency count tables can be found in Appendix H.

research question 2 and Project 2061 assessment items.

The second research question asks, "How does participating in the school garden inquiry unit affect students' scientific practices?" Students were asked to answer eight multiple-choice questions. These questions were selected from the Project2061 assessment bank (AAAS, 2013). These questions were specifically selected to better understand whether students can gain knowledge about the process of scientific inquiry and then apply this knowledge to a science practice. These eight questions are content-driven and represent the understanding and application of the actual practices of modeling and control of variables. Both of these practices are found in NGSS practices (3 and 5). The use of these practices demonstrate whether students are able to create knowledge about the process of scientific inquiry and then apply this knowledge to a given situation, i.e., modeling and control of variables strategy. Demonstrating the application of the knowledge gained about the nature of scientific inquiry is another important part of the process of scientific inquiry.

Table 10 below contains the statistics for student responses from both the treatment (pre-test and post-test) and the comparison group's post-tests. Items were scored for correctness for a maximum score of 8 and a minimum score of 0. The unit of analysis is the class (treatment group total *n* = 50 and comparison class total *n* = 26).

Table 10. *Student Responses to Project2061 Multiple Choice Questions.*

Question #	Correct Answer	Concept	T Pre		T Post		C Post		Misconception Answers
1	C	Control Variable Strategy	*M* = .440	*SD* = .501	*M* = .723	*SD* = .452	*M* = .500	*SD* = .511	B, D
2	C	Control Variable Strategy	*M* = .360	*SD* = .485	*M* = .319	*SD* = .471	*M* = .333	*SD* = .482	A, B, D
3	A	Control Variable Strategy	*M* = .180	*SD* = .388	*M* = .277	*SD* = .452	*M* = .208	*SD* = .415	B, C
4	D	Control Variable Strategy	*M* = .080	*SD* = .274	*M* = .149	*SD* = .359	*M* = .083	*SD* = .282	A, B
5	D	Control Variable Strategy	*M* = .140	*SD* = .351	*M* = .426	*SD* = .499	*M* = .042	*SD* = .204	A, B
6	C	Modeling	*M* = .240	*SD* = .431	*M* = .192	*SD* = .397	*M* = .292	*SD* = .464	
7	A	Modeling	*M* = .360	*SD* = .485	*M* = .511	*SD* = .505	*M* = .083	*SD* = .282	B, D
8	C	Modeling	*M* = .620	*SD* = .490	*M* = .894	*SD* = .312	*M* = .583	*SD* = .504	
Total Score			*M* = 2.391	*SD* = 1.325	*M* = 3.489	*SD* = 1.692	*M* = 2.125	*SD* = 1.227	
			Missing = 1		Missing = 4		Missing = 0		

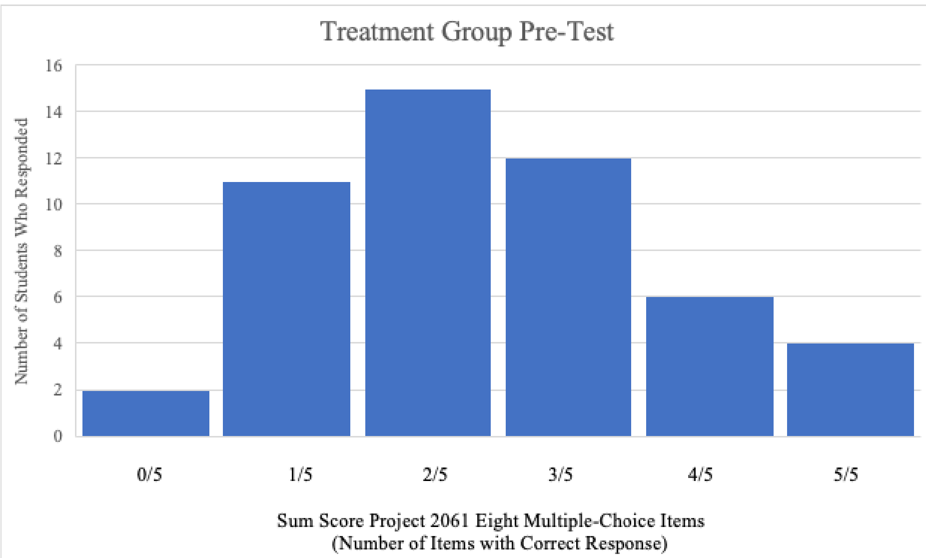
**Across treatment post-test answers Cronbach's Alpha = 0.536,*
**Across treatment post-test and comparison answers Cronbach's Alpha = 0.510*

Two different t-tests analyses were conducted to better understand how the school-garden inquiry intervention affected each group's Project 2061scores. A paired samples t-test was conducted over the treatment group’s pre-test and post-test scores. An independent samples t-test was conducted over the treatment group’s and comparison group’s post-test scores. Assumptions were made regarding the created scale of the eight Project 2061items, the randomness of sampling, the normality of the data distribution, and the adequacy of sample size (Bakker & Wicherts, 2014).

treatment group.

The researcher first assessed whether the treatment group gained on its Project 2061 post-test scores. A paired samples t-test was conducted to compare whether the school-garden intervention affected students’ multiple-choice test scores from pre-test to post-test. The paired sample t-test has four main assumptions: 1) The dependent variable must be continuous (interval/ratio); 2) The independent variable should consist of two categorical "related groups" or "matched pairs"; 3) There should be no significant outliers in the differences between the two related groups; and 4) The distribution of the differences in the dependent variable between the two related groups should be approximately normally distributed (Boneau, 1960; Mara & Cribbie, 2012; Ross & Wilson, 2018).

The researcher checked for paired samples t-test assumptions before conducting analysis. The dependent variable, Project 2061 scale, was continuous (see Table 10), the independent variable is consistent with two matched pairs (treatment group pre-test scores matched with treatment group post-test scores), and a normal distribution was found between the treatment group’s pre-test and post-test scores, see Figures 4 and 5 below (Boneau, 1960; Mara & Cribbie, 2012; Ross & Wilson, 2018). In addition, the skewness and kurtosis were also calculated to better understand the symmetry and height of each data set. The treatment group pre-test displayed a skewness of 0.33. Because this is between -0.5 and 0.5, the distribution is approximately symmetric. The treatment group pre-test also displayed a kurtosis of -0.49. Because this is between the values of -3.0 and 3.0, the distribution is normal. The treatment group post-test displayed a skewness of 0.10. Because this is between -0.5 and 0.5, the distribution is approximately symmetric (Groeneveld & Meeden, 1984). In addition, the kurtosis was calculated for the treatment group post-test and was found to be -.19. Because this is between-3.0 and 3.0, the distribution is normal (Groeneveld & Meeden, 1984).

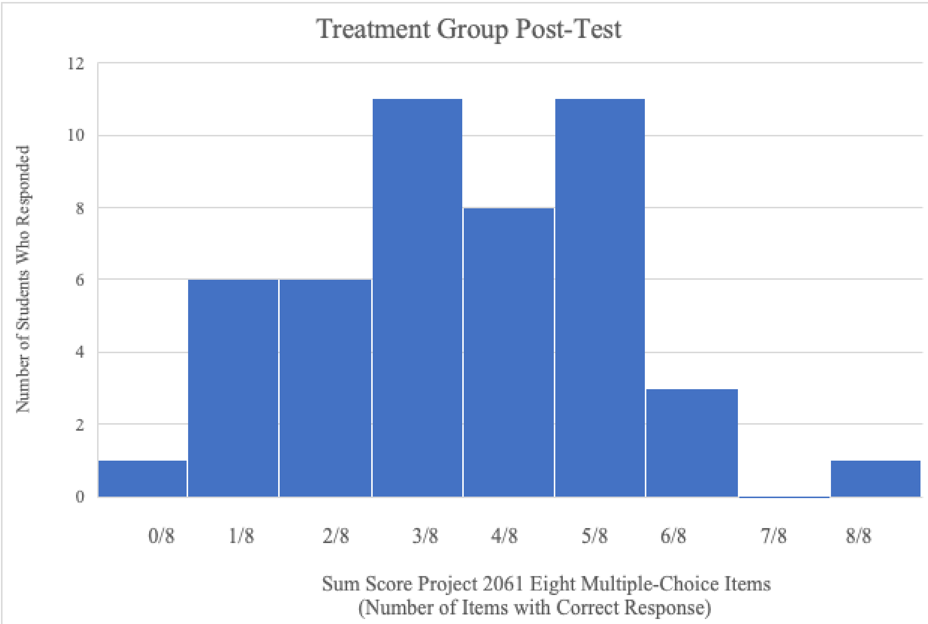


Mean = 2.42

Standard Deviation = 1.29

N = 50

Figure 4. *A histogram displaying the normal distribution across the treatment group's pre-test scores. Each column represents a score, 0 through 5. No student answered more than five items correctly.*



Mean = 3.49

Standard Deviation = 1.69

N = 47

Figure 5. *A histogram displaying the normal distribution across the treatment group's post-test scores. Each column represents a score, 0 through 8. Only one student answered all eight items correctly.*

After assumption checking was completed, the researcher found no violations and continued with the paired samples t-test analysis. There was a significant difference in the scores between post-test (*M* = 3.533, *SD* = 1.632, *SE* = .243) and pre-test scores (*M* = 2.422, *SD* = 1.322, *SE* = .243); $t(45)= 4.397$, $p = 0.00$; 95% CI (.602, 1.620). These results suggest that the school-garden inquiry intervention does affect students learning, specifically about the science practices of modeling and control of variables.

The effect size (Cohen's *d*) was then calculated to investigate the kind of affect the intervention produced with the treatment group students, Cohen's $d = ((2.422 – 3.533)/ 1.632) = .681$, demonstrating that the intervention had a moderate affect with the treatment group students (Cohen, 1988).

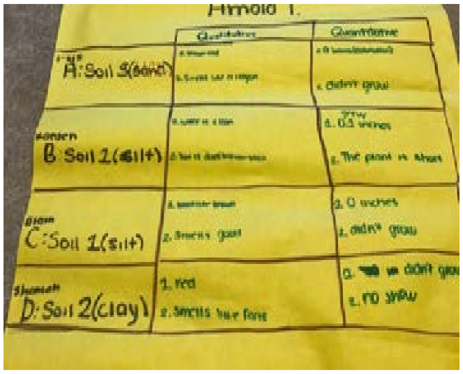
Consequently, when looking at the students' scores from both pre-test and post-test, these scores do not demonstrate a passing grade. However, for the purpose of this dissertation the researcher is not looking at a passing score; instead the research is interested in knowledge gains. From pre-test to post-test the treatment group students do demonstrate gains on their Project2061 scores. These gains are small but enough to demonstrate that students are learning from when they initially took the pre-test to the end of the intervention when the post-test was taken.

items focusing on control of variables strategy (CVS).

The first five items ask understanding about the practice, control of variables strategy. As explained in chapter three, this is a NGSS practice. For students to perform investigations correctly they must understand the relationship between variables. The items for this measure were specifically chosen because each question relates to plants or agriculture, see Table 11 below. This was purposefully done to help students find associations between what the items are asking and what activities the students are exposed to.

Table 11. *Displaying the context of each CVS item.*

Item Number	Item Context
1	The effect of sunlight on plants.
2	The effects on plants and different soils.
3	How the number of fish and light settings effect water temperature.
4	How different amounts of water affect the growth of seedlings.
5	How different types of fertilizer affect the growth of plants.



6.a.

6.b.

Figures 6.a. and 6.b. *Displaying student work from lesson 3.1, How to Plan an Experiment. In this lesson students planned and conducted an experiment about types of soil. Students were being exposed to CVS.*

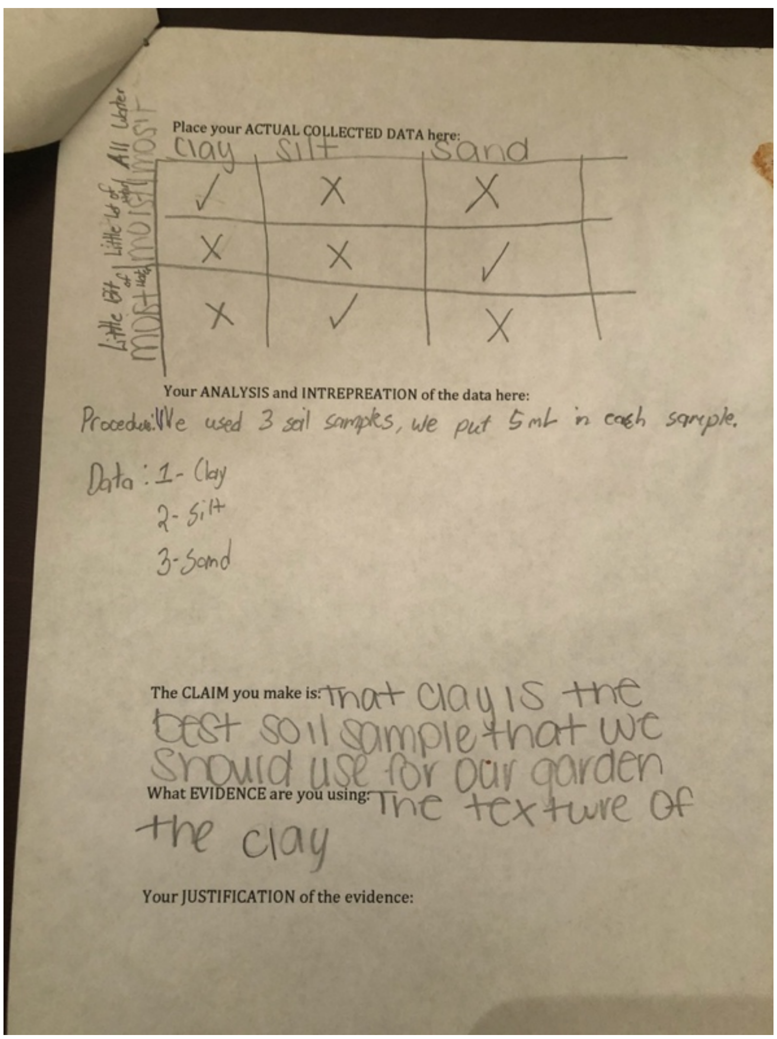
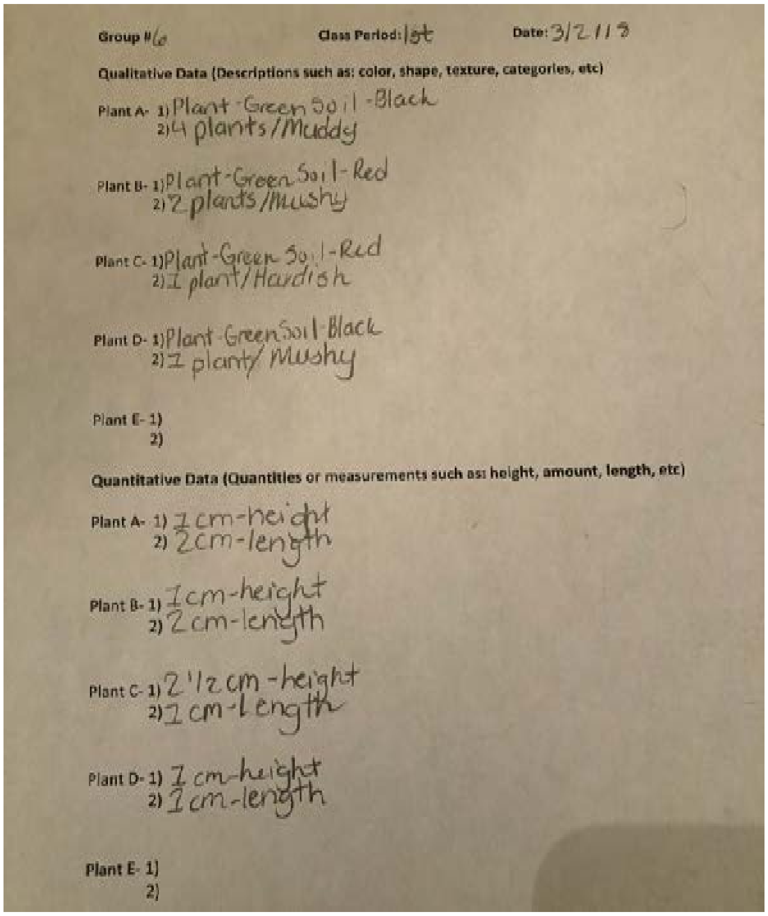


Figure 7. *Student work from lesson 3.1, How to Plan an Experiment. Students created their own experiments to investigate which type of soil was best for growing plants.*


8.a.

8.b.

Figures 8.a. and 7.b. *Students collected data in lesson 3.2, Understanding Types of Data, from their soil experiment to better understand which soil sample was best for their school garden. This lesson helped students understand that soil type was a variable.*



Group #6 Class Period: 1st Date: 3/2/18

Qualitative Data (Descriptions such as: color, shape, texture, categories, etc)

Plant A- 1) Plant-Green Soil-Black
2) 4 plants/Muddy

Plant B- 1) Plant-Green Soil-Red
2) 2 plants/Mushy

Plant C- 1) Plant-Green Soil-Red
2) 1 plant/Hardish

Plant D- 1) Plant-Green Soil-Black
2) 1 plant/ Mushy

Plant E- 1)
2)

Quantitative Data (Quantities or measurements such as: height, amount, length, etc)

Plant A- 1) 1 cm-height
2) 2 cm-length

Plant B- 1) 1 cm-height
2) 2 cm-length

Plant C- 1) 2 1/2 cm-height
2) 1 cm-Length

Plant D- 1) 1 cm-height
2) 1 cm-length

Plant E- 1)
2)

Figure 9. *Student work from lesson 3.2, Understanding Types of Data. From their data, students better understood which soil type or variable affected plant growth.*

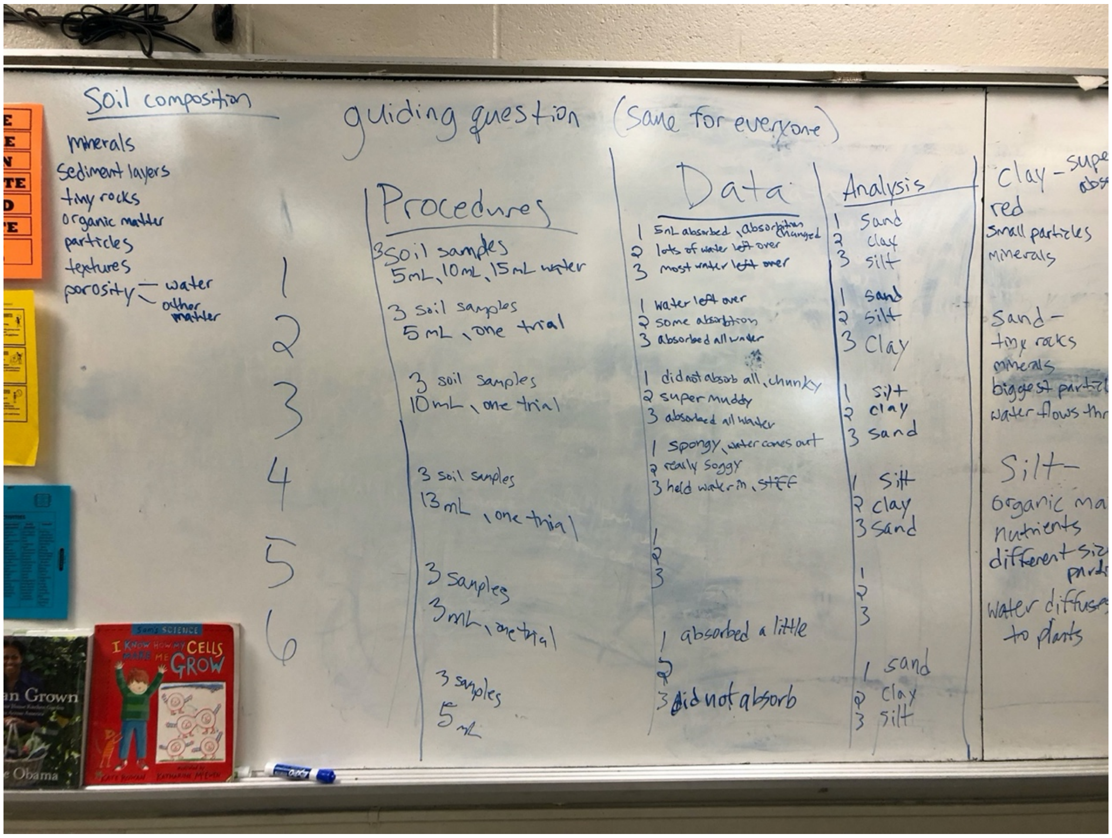


Figure 10. *This figure displays how members of each group set up their soil experiment in lesson 3.1, How Do Procedures Affect Results. The procedures and results from each group were written on the classroom board to allow students to compare the different groups' procedures. Note that some of the groups remembered to control a variable, but not all groups.*

 11.a.  11.b.

Figures 11.a. and 11.b. *In lesson, 5.3, Construction of Engineering Design, students used their knowledge about soil from their CVS experiments. Students chose silt for their school garden.*

The figures above demonstrate how the students were exposed to the practice CVS throughout the various school garden lessons. A sum score over the five CVS items was created. Treatment group pre-test (n = 50, M = 1.2, SD = 0.97) and treatment group post-test (n = 47, M = 1.9, SD, = 1.2). The sum scores from pre-test to post-test show change.

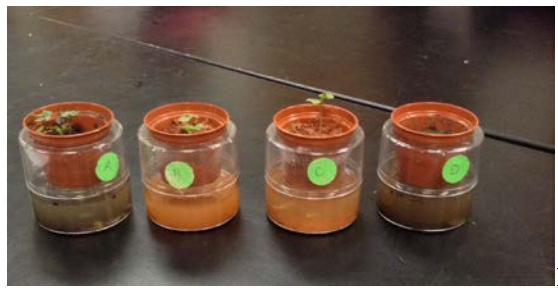
items focused on modeling.

The last three Project 2061 items ask about the NGSS practice modeling and understanding about this practice. Students needed to demonstrate their understanding about how models are used in the scientific and engineering communities. The items chosen for this measure were chosen because each question relates to an aspect of modeling, see Table 12 below. However, none of these items are situated in context about plants or the environment.

Table 12. *Displaying the context of each modeling item.*

Item Number	Item Context
6	A statement asking about characteristics of modeling.
7	When making a model of a ship, what should be represented?
8	Abstract question - what is considered a model?


12.a.


12.b.


12.c.

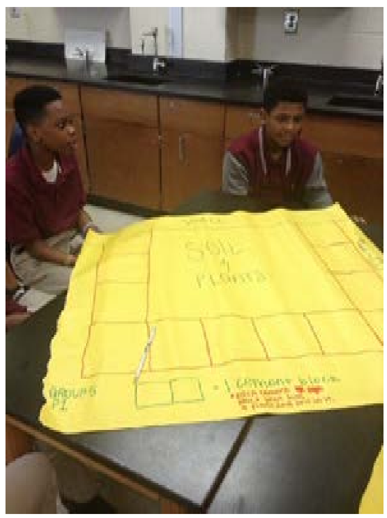

12.d.

12.e.

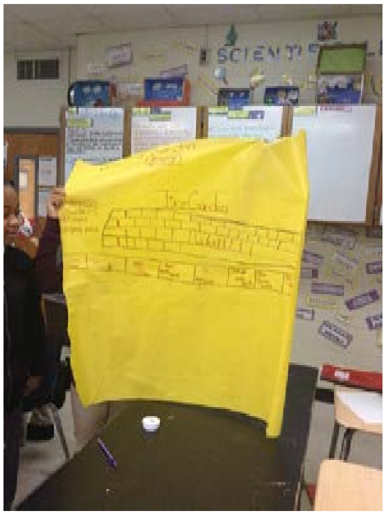
12.f.

Figures 12a. - 12.f. *From lesson 3.1 through lesson 5.1 students participated in the creation of an indoor garden. This indoor garden was supposed to be a smaller version of their future out-door garden. This indoor garden allowed students to better understand the variables of soil and water.*

13.a.



13.b.


13.c.


13.d.

Figures 13.a. – 13.d. *In lesson 5.1, Learning How to Design, each group of students researched and created a design for the school garden. In Figures 13a and 13b, students created and drew their ideas. In Figures 13c and 13d each group of students presented its design to the class.*

14.a.


14.b.

Figures 14.a. and 14.b. *In lesson 5.2, Evaluation of Engineering Design, students were participating in a silent gallery walk. During this gallery walk students were able to see what other groups had designed. Students were also evaluating each other's designs by leaving critiques and comments on post-it notes.*

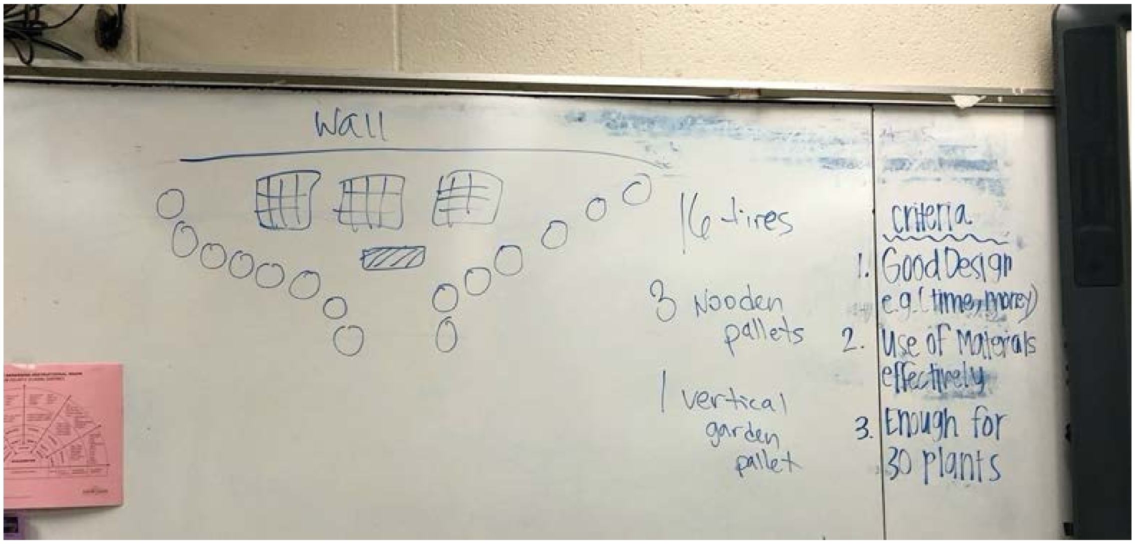
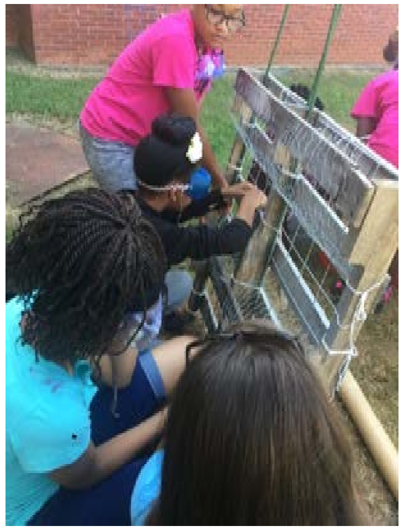


Figure 15. *The final completed design for the school garden. Students were able to negotiate with one another and the three group designs were integrated to create the final school garden design.*

Figure 16.a. Figure 16.b. Figure 16.c.

Figures 16a., 16.b., and 16.c. *In the final lesson, 5.3, Construction of Engineering Design, students took the design they created and constructed their school garden based on their design.*


a.


b.


c.


d.

Figures 17.a. – 17.d. *These four figures show the process of how one group of students came up with the design of creating a vertical garden (Figure 17.a), to the construction of the vertical garden (Figure 17.b), to the final result of the completed vertical garden (Figures 17.c and 17.d).*

 a.  b.

Figures 18.a. and 18.b. *In Figure a, the students work on their design for the school garden. In Figure b the students were actually able to construct the design they created.*

Figure 19. *This is a photograph of the completed school garden as constructed. The final construction appears almost identical to the final school garden design drawn by the students*.

changes in treatment group.

A sum score over the three modeling items was created. Treatment group pre-test descriptive statistics (n = 50, M = 1.2, SD = 0.86). Treatment group post-test descriptive test (n = 47), M = 1.6, SD = 0.74). The sum scores from pre-test to post-test show change. The figures above demonstrate how the students were exposed to the practice of modeling throughout the various school garden lessons. As seen from the figures, students were exposed to modeling in two different forms, the perspective of a scientist (indoor garden) and the perspective of an engineer (design and construction of the school garden).

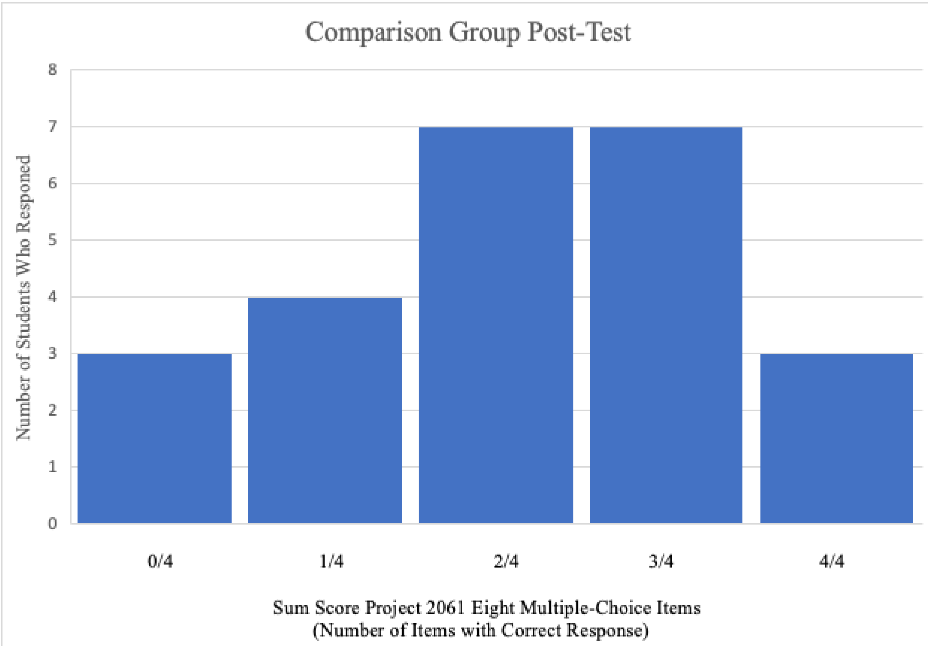
At the beginning of this chapter, it was explained that only the post-test was administered to the comparison group. Descriptive statistics were calculated for the comparison group post-test scores: $n = 24$, $M = 2.125$, $SD = 1.227$, $SE = 0.251$. In addition, descriptive statistics were calculated for each practice: control of variables strategy ($n = 24$, $M = 1.17$, $SD = 0.92$) and modeling ($n = 24$, $M = 0.96$, $SD = 0.86$). From these descriptive statistics, students in the comparison group do not show passing scores.

comparison group and treatment group post-test scores.

To investigate differences between the two groups, the researcher first assessed whether there were differences between the two groups' Project 2061 post-test scores. Descriptive statistics were first calculated: mean, standard deviation, and standard error between both groups' post-test scores. Treatment group post-test scores: $n = 47$, $M = 3.489$, $SD = 1.690$, $SE = 0.247$ and the comparison group post-test scores: $n = 24$, $M = 2.125$, $SD = 1.227$, $SE = 0.251$. Differences were found between the two groups' post-test scores and, therefore, the researcher conducted an independent t-test analysis.

An independent samples t-test was conducted to compare if the school-garden intervention affected students' Project 2061 post-test scores between the treatment group and the comparison group. Before the analysis could be conducted, assumption checking for an independent samples t-test occurred. The independent samples t-test has three main assumptions: 1) The observations are independent of one another, 2) Normality of the dependent data: the dependent variable must follow a normal distribution, and 3) Homogeneity, the distribution of scores around the mean of two or more samples are considered equal (Bakker& Wicherts, 2014, Barnard, 1984; Feir-Walsh & Toothaker, 1974; Levene, 1960; Rasch, Teuscher, & Guiard, 2007; Rochon, Gondan, & Kieser, 2012; Ross & Willson, 2018).

The researcher checked for independent samples t-tests assumptions before conducting the analysis. The sampling was random and the scores were independent of each other; the treatment group and comparison group were students on different teams. A normal distribution was found between the treatment group (see Figure 18 below) and the comparison group's post-test scores (see Figure 19 below). Figure 20 below depicts how the overall combined post-test scores fall into a normal distribution. Furthermore, the comparison group (n = 24) displayed a skewness of -.26. Because this is between -0.5 and 0.5, the distribution is approximately symmetric. In addition, the kurtosis was calculated for the comparison group post-test and was found to be -.73. Because this is between -3.0 and 3.0, the distribution is normal (Groeneveld & Meeden, 1984). And, as described earlier, the treatment group post-test displayed a skewness of 0.10. As this is between -0.5 and 0.5, the distribution is approximately symmetric. In addition, the kurtosis was calculated for the treatment group post-test and determined to be -.19. Because this is between -3.0 and 3.0, the distribution is normal (Groeneveld & Meeden, 1984). And Levene's test of homogeneity, was calculated with a score of p = 0.602, demonstrating that the two samples have equal variances and that random sampling did occur in this population (Levene, 1960).

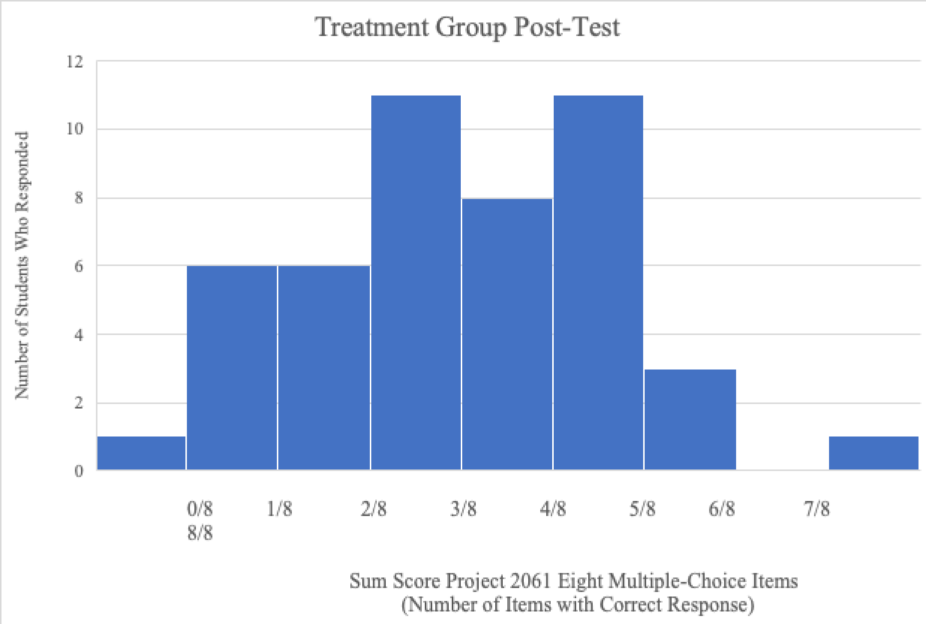


Mean = 2.13

Standard Deviation = 1.23

N =24

Figure 20. *This histogram demonstrates the comparison group's post-test scores and that the scores are normally distributed. Each column represents a score, 0 through 4. No student answered more than four items correctly.*

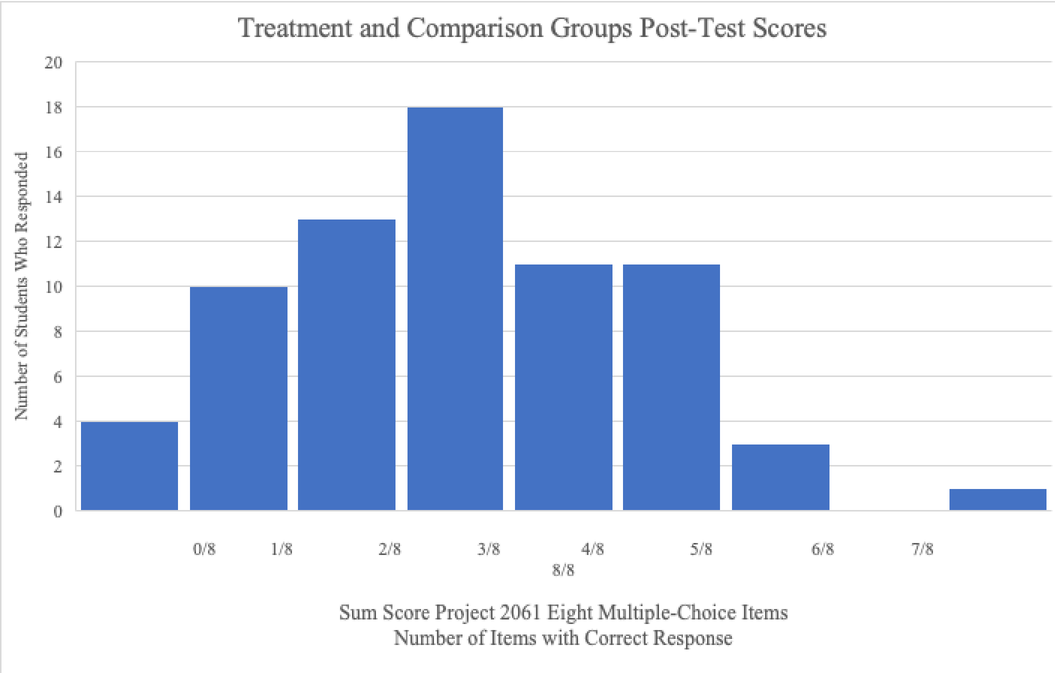


Mean = 3.49

Standard Deviation = 1.69

N = 47

Figure 21. *This histogram demonstrates the treatment group's post-test scores and that the scores are normally distributed. Each column represents a score, 0 through 8. Only one student answered all eight items correctly.*



Mean = 3.03

Standard Deviation = 1.67

N= 71

Figure 21. *This histogram demonstrates post-test scores from both groups and that the scores overall demonstrate a normal distribution. Each column represents a score, 0 through 8. Only one student answered all eight items correctly.*

After assumption checking was completed, the researcher found no violations and continued with the independent samples t-test analysis. Due to the mean differences between both groups, an independent samples t-test was conducted to investigate if there were statistical differences in post-test scores between the groups: treatment group (M = 3.489, SD = 1.690) and comparison group (M = 2.125, SD = 1.227). There was a statistically significant difference between both groups' post-test scores; students in the treatment group received higher scores $t(69) = 3.502$, $p = .001$ (Barnard, 1984; Feir-Walsh & Toothaker, 1974). The results indicate that participation in the school-garden inquiry intervention does significantly affect a student's Project2061 post-test scores. Therefore, students who participated in the school garden inquiry intervention had statistically higher Project2061 post-test scores than students in the comparison group.

In addition, because there was a large difference between sample size across both groups: treatment *n* = 47, and comparison *n* = 24, it was important to also calculate the effect size of the intervention between the two groups (Fern & Monroe, 1996; Fritz, Morris, & Richler, 2011). By doing so, it is easier to discuss the relative magnitude of the effects of the intervention on the student's learning about science practices. Cohen's *d* was calculated using means and standard deviations of both groups (treatment *M* = 3.489, *SD* = 1.692) and (comparison *M* = 2.125, *SD* = 1.227), Cohens' *d* = .9231, *r* = .0419 (Cohen, 1988; Fern & Monroe, 1996; Fritz, Morris, & Richler, 2011). Therefore, the intervention had a large effect; 82% of the comparison group would score below an average student found in the treatment group. Overall, the intervention did have an effect on student science practices.

5 DISCUSSION

This study investigated the creation of new scientific knowledge through the process of inquiry and the application of this knowledge through scientific practices. The context for this study naturally highlights ideas from the fields of science and engineering, in a school garden. The decision to conduct this investigation within the setting of a school garden appeared to be an organic fit. The school-garden intervention introduced a group of sixth grade students to eight NOSI aspects and NGSS scientific practices through engagement in garden-oriented inquiry activities. NOSI aspects and NGSS scientific practices were made explicit by discussing them in context of the school garden inquiry activities, i.e., miniature indoor garden or design competition as well as having students reflect on how professionals perform similar activities in their careers. This final chapter will identify the various features that all played a role in this school garden intervention.

The discussion is organized by research question: 1). How are students' understanding about scientific inquiry affected by participation in a school garden intervention? and 2). How are students' application of scientific practices affected by participation in a school garden intervention? Each research question was answered with two different groups of students. The treatment group, students who participated in the school garden intervention, and the comparison group, students who learned science in their typical sixth grade classroom.

The findings demonstrate how urban middle schoolers' views about scientific inquiry and their knowledge about scientific practices changed through the participation in a school garden intervention. This investigation shows that school gardens can be utilized as another type of out-of-classroom setting where various disciplines can be explored, more specifically science and engineering. Furthermore, the findings support the use of project- and problem-based learning as an instructional method; the students created both an indoor garden and an outdoor garden and found solutions for fighting hunger in their community. The chapter will close by discussing how a school garden is an alternative way for students to experience more authentic science and engineering situations. This authentic approach may be an avenue to combat the larger overarching problem in K- 12 science education, i.e., scientific literacy.

Understanding the process of inquiry

The first research question asked: How are students' understanding about scientific inquiry affected by participation in a school garden intervention? To answer the question students filled out the qualitative assessment Views About Scientific Inquiry (VASI) modified. The assessment included eight open-ended items; the eight items align with the eight targeted NOSI aspects. This alignment by aspect allowed for a more in depth understanding behind which aspects were more difficult for these middle schoolers to grasp even after participating in a school garden intervention. Additionally, throughout this section "teacher" is referring to the researcher teaching the classes.

treatment group NOSI changes.

The treatment group demonstrated change from naive views to more informed views about inquiry across all eight aspects of NOSI. Each aspect will be discussed independently and if changes were demonstrated in the treatment group. The school garden intervention was found to be most effective in developing four of the eight aspects.

Aspect "*there is no single set and sequence of steps followed in all scientific investigations (i.e., there is no single scientific method)*" is divided into three parts and examined the different types of investigations in the domain of science. At pretest, naive views were 58.8% and informed 3.9%, but by posttest naive views had decreased to 35.3% and informed views had increased to 19.6%. Students in the intervention were constantly exposed to two types of investigations, observational and experimental. Throughout the lessons, students began to recognize that different ideas could create different types of investigations. In lesson 2.1, students designed and conducted an observational study. Then in lesson 2.2, students designed and conducted an experimental study. It was up to each group to design an observational investigation followed by the design of an experimental investigation. During these lessons, the researcher was mindful to continuously move from group to group to assist in each group's understanding about what key differences occur in these two types of investigations. The pedagogical approach for lessons 2.1 and 2.2 were student-centered situated learning, the students within each group had agency to design and conduct their own investigations. By allowing, the students to design and conduct their own investigations, they appeared more engaged with the material and created associations that were relevant and unique to the individual investigations which they designed.

For the following aspect, "*scientific data are not the same as scientific evidence*" students did demonstrate understanding. At the time of pretest, 62.7% of the students demonstrated a naive view and 9.8% demonstrated informed views. By the time of the posttest, naive views had declined to 29.4% and informed views increased to 33.3%. The students in the treatment group explicitly discussed the differences between data and evidence in lessons 2.2, 3.1, and 3.2 with each other and the researcher. These lessons included worksheets where students designed investigations, carried out the investigation, analyzed the data, and justified claims with evidence from their investigations. The three lessons aligned with the desired aspect, allowing groups to practice gathering data and to learn how to interpret their data so that it became evidence. Across all fidelity observations, the researcher did discuss data and evidence with the students. The researcher emphasized to students how scientists collect information (their data) but that the information cannot become evidence until the scientists analyze and interpret the data in a manner that supports the research question. Understanding the key differences between those two science terms empowers students' scientific literacy. It is important for students to evaluate scientific claims and one way they learn this practice is by understanding the difference between data and evidence. This understanding between data and evidence is seen in everyday life e.g. media, politics, etc. supporting the importance of learning how to evaluate scientific claims. In the intervention students would have the ability to make claims supported by data which they had collected and interpreted which would thereby become evidence.

By the end of the intervention, there remained a few students who continued to have naive views about evidence see Table 10. These students still related evidence to a crime scene or law. This may be due to the way evidence is portrayed in today's media, i.e., Law and Order, CSI, etc. These television shows act out the practices of what scientists do on the job but there is no explanation discussing how data found at a crime scene becomes evidence in the courtroom (Brossard, & Scheufele, 2013; Songer, 2007; Szu, Osborne, & Patterson, 2017). Due to the lack of explanation from television shows and media, students often create misconceptions about the world of science (Krajcik & Mun, 2014; Nisbet & Dudo, 2011).

In aspect "*inquiry procedures are guided by the question asked; questions drive the process.*" Students demonstrated significant change in their understanding. At pretest, a large plurality (47.1%) of students held naive views, with only 11.8% demonstrating informed views. By posttest only 17.6% of students held naive views and informed views increased to 25.5%. The large change to mixed and informed responses could be attributed to the format of each lesson and the pedagogical approach of the teacher. The beginning of each lesson started with the teacher discussing with the class background information on a given topic as well as asking students what they know. This student-center approach of asking students questions and their prior knowledge allowed the students to drive the discussion. By the end of the short discussion, the teacher would then ask the class with the information they did have what they could ask as a class, known as the guiding question. Once the class decided upon the guiding question, the teacher placed it on the board. The board was a public area for all students to view. If students happened to forget what the day's lesson was, they could simply look at the board. The teacher was also mindful in going around to groups during each lesson and having the group members explain how the guiding question drove what is happening in the day's activities. Moreover, as indicated in the fidelity observation sheets, the teacher explicitly discussed the importance of procedures aligning with the questions asked.

Finally, the aspect where students displayed a significant shift in understanding was over the aspect "*research conclusions must be consistent with the data collected*". The responses to this aspect demonstrated the largest gains in understanding; at pretest 29.4% held naive views and 49% held informed views. However, by posttest only 5.9% held naive views, the remaining students held mixed or informed views. As explained with the aspect *"data and evidence are not the same"*, the researcher explicitly discussed the importance of evidence throughout the five lessons. Nevertheless, specifically in lessons 2.1, 2.2, 3.1 and 3.2, the researcher took time to have each group present their data to the entire class and then hold a class discussion where the class data was written on the board. After the class discussion, each group would then have to write a claim and explain what data they used and how it was analyzed to become evidence. In lessons 3.1 and 3.2, the students planted Fast Growing plants and took quantitative and qualitative data points of their plants for three weeks. The activity of working with plants may have influenced students' understanding about this aspect because the question itself on the VASI asked about plant growing, an activity that all students were exposed to throughout the school garden intervention.

The school garden intervention moderately impacted student views of three other NOSI aspects. In the aspect "s*cientific investigations all begin with a question but do not necessarily test a hypothesis",* the majority (58.8%) of the students at pretest held naive views and 19.6% held informed views. By posttest there was a 10% change towards greater understanding that scientific questions are needed because the question sets the stage for the topic of the investigation. At posttest, the students' naive responses had dropped to 45.1% and informed views increased to 31.4%. As indicated in previous aspects, throughout all of the lessons, students were exposed to the concept of guiding questions and how a question plays a role in an investigation. This aspect may have only reached moderate understanding because the teacher was not explicit enough with students in explaining the connection between a question and how the question leads to the topic of an investigation.

The aspect "*all scientists performing the same procedures may not get the same conclusions"* proved to be difficult because it explored the notion of human individuation, e.g., prior knowledge, experiences, culture, and how these factors all influence how an individual will analyze and interpret data. It is these individual differences that can cause research groups with the same research question and same procedures to arrive at completely different conclusions. Some of the students were able to grasp that this aspect explores how individual human differences can affect conclusions. At pretest many students (66.7%) held naive views and 11.8% held informed views. By posttest, informed views increased to 21.6% and naive views decreased to 43.1%. Students worked in groups for all lessons so that they would have first-hand experience of what it is like to collaborate with peers who may not have the same thoughts. In addition, in every lesson, the researcher wrote each group's data on the board with their claim. This allowed students to see, even within their class, how groups can have different data and different conclusions even when they all started with the same guiding question. But as shown on the fidelity observation sheets, the researcher did not explicitly explain subjectivity and human individuation to the class. The researcher assumed that the students would make this connection about individual differences on their own. However, as demonstrated in the findings, not all students grasped the concept of human individuation during the process of inquiry. This is another indication as to why explicit and reflective connections between activities and NOSI aspects must be made by the teacher.

However, the school garden intervention seemed to be less effective in developing ideas around the aspects of "*inquiry procedures can influence the conclusions*" and *"explanations are developed from a combination of collected data and what is already known."* Across the eight NOSI aspects, these were the most difficult for the sixth-grade students to fully understand. For the aspect *inquiry procedures can influence the conclusions* at pretest, students held naive 31.4%, mixed 47.1%, informed 4%. By posttest students' responses had minimally changed naive to 25.5%, mixed 49%, and informed 4% (no change). Many of the students agreed that different procedures can lead to different conclusions, but the students could not articulate this in the rationale portion of their response. These questions can also be viewed as "interpretation" questions. It is up to the individual to frame how they will understand an idea and this generally is developed from an individual's prior knowledge and experiences through life. Fidelity observations indicate the concepts of subjectiveness and human individuation were not extensively discussed in depth throughout the intervention, see Table 8. It was difficult for students to understand that these individual differences can stem from trying to answer the same question and scientists are individuals with their own experiences and bodies of knowledge, which can affect how problems are solved. Human individuation and how this influence's design and interpretation in turn leading to different types of investigations and conclusions for the same question needed to be touched on more extensively with the students. In all five lessons, students were given the same guiding question, but the researcher allowed the groups the flexibility to answer the question in whatever means worked for the group. Therefore, in reality the groups were all exposed to this aspect, but the researcher did not make that connection explicit between aspect and activity for the students. In general, it appears to be a concept that is difficult for this overall population of students to grasp with the limited explicit attention provided in these lessons.

To measure the aspect *explanations are developed from a combination of collected data and what is already known* item 7 on the VASI, it is split into two parts; (a) asked students to make a claim using evidence and (b) asked students what other kinds of information could help support their original claim. For many of the students, part (a) was easily answered, using evidence to support a claim. However, the second part of the question did not connect with the students, i.e., that others before us have made scientific discoveries and those discoveries can support current claims. The concept of a person making scientific discoveries a hundred years ago and how this discovery has shaped science in our current society did not connect with the majority of students. Due to this misunderstanding about how discoveries create new information, students displayed only a small change from pretest to posttest. Naive views 51% dropped to 43.1%, mixed views increased from 29.4% to 37.3%, and informed views actually decreased from 17.6% to 11.8%. One major flaw that students demonstrated in their responses was the claim that the use of technology, such as the internet was a source of evidence. Students did not demonstrate an in-depth understanding that technology was a way to find evidence or to use during an investigation. Many students demonstrated a large misconception about the role of technology in science and engineering (Songer, 2007; Wallace, Kupperman, Krajcik, & Soloway, 2000). This misunderstanding involving technology and current K- 12 students has been expressed by several researchers in the last decade (Brossard & Scheufele, 2013; Krajcik, & Mun, 2014; McCrory, Kupperman, Krajcik, & Soloway, 2000; Nisbet & Dudo, 2011; Songer, 2007; Szu, Osborne, & Patterson, 2017). It is becoming apparent that how technology and media are used in the fields of science and engineering are not being discussed with the current generation of students. The discussion of media and technology in the student responses as a way to find information which could become evidence may be attributed to the constant use of technology during the lessons with the teacher. Throughout the intervention the groups were allowed to use ipads and the internet as a way to research their ideas. When students were asked how to find other evidence to support their claims students' responses used terms, e.g., the internet, use Google, or look on the computer. Students were not realizing that the technology they are claiming as a form of evidence is actually only a conduit to find information. Technology is a way to find or create new knowledge but to these students, technology is only a way of *information seeking* (Krajcik & Mun, 2014; Wallace, Kupperman, Krajcik, & Soloway, 2000). Instead technology is hindering this current generation of students because they are forgetting that individuals are still making discoveries and contributing to the fields of science and engineering. This constant use of technology in the classroom without explicit discussion over why technology and media are used during investigations was noted by the researcher during the analysis phase. Students are confusing technology with the *accessibility* to find information. The internet and search engines like Google may help students find information more easily but the question remains who created the information found on the internet and Google. Is that information reliable? The researcher noted how many students used a Google search and clicked on the first few web pages rather than evaluate the kind of information presented on each website. Today's generations of students are choosing blogs or opinionated websites rather than trying to find objective websites (Brossard & Scheufele, 2013). The internet and search engines are a way for *information seeking*; students are looking for the perfect answer as fast as they can (Krajcik, & Mun, 2014; Kupperman, Krajcik, & Soloway, 2000). Rather than taking the time to actually read the content found on each website, instead students are simply looking for keywords. From student responses, it appears that students have not necessarily thought about the kinds of information they find with the use of technology. Therefore, students displayed a poor ability to evaluate websites. This relates back to the students not understanding the connection between claims and evidence. Students found the websites but would blindly ingest the information they found rather than being more careful and recognizing that the claims on these websites should be supported by evidence. It appears that when students are asked to *research*, this is synonymous with using the internet and search engines. This finding will help researchers think about the impact of technology and media on the younger generations who have always been in a world inundated with technology and media and how this inundation affects how students view the use of technology and media and the creation of knowledge. There is a lack in the practice of evaluating these websites on the internet. From the findings of this intervention, the researcher noted that students need more scaffolding and activities to have an in-depth understanding of the role technology plays in science and engineering (Nisbet & Dudo, 2011; Szu, Osborne, & Patterson, 2017; Wallace, Kupperman, Krajcik, & Soloway, 2000). In addition, the way students are using technology and media in today's classrooms should be noted because it may be affecting how students understand the process of inquiry and how to find information to support their ideas (Brossard & Scheufele, 2013; McCrory, Kupperman, Krajcik, & Soloway, 2000).

model competence.

The last aspect in which students displayed moderate growth was the aspect, "*explanations and models are developed from a combination of collected data and what is already known.*" This aspect is actually being measured with an item from another measure, VNOS (see chapter 3) but because this item explores modeling, a relevant practice in science and engineering, it was incorporated into the original pretest and posttest measures for this school garden intervention. Models and the process of modeling are useful tools for conducting investigations, analyzing data, and communicating information as explained in this aspect (Schwartz, 2018; Schwartz & Skjold, 2012; Schwarz & White, 2005). Across all three categories growth was demonstrated from pretest (naive 72.3%, mixed 19.6%, and informed 3.9%) to posttest (naive 31.4% and increases in mixed 49% and informed 11.8%). At the beginning of the intervention students viewed modeling as concrete, a visual representation, or a product; a typical school science perspective, a model is a visual aid (Schwartz, 2018; Schwartz & Skjold, 2012). But through the lessons and explicit instruction, students began to change their views to realize that models can also be something abstract, such as a process. By the end of the intervention, students realized that models are used to explain or organize observations, as seen with their miniature indoor garden. Moreover, models are used to predict and then test through further observations (Schwartz, 2018; Schwartz & Skjold, 2012). It was through the authentic experiences of creating and designing models that the students by the end of the intervention realized that models can be used to investigate a question or to collect data in addition to a representation (Crawford, 2012). A greater change in understanding how scientists and engineers use modeling in their professions was assumed to have occurred with the treatment group students. However, a disconnect between comprehending how scientists and engineers use models in their everyday work was still noted at the end of the intervention. The assumption that students would begin to comprehend how professionals use models was made due to the different types of modeling intertwined in the lessons. In lessons 3.1 and 3.2, students created a miniature indoor garden as a type of model for their future outdoor garden. Later in lessons 5.1, 5.2, and 5.3, students designed prototypes of their outdoor gardens. Both lessons used modeling but in different ways; lessons 3.1 and 3.2 involved gathering data and lessons 5.1, 5.2, and 5.3 involved the iterative process of design and the application of constraints. In those lessons, models help explain and support an idea or how to solve a problem. However, even with the various practices of modeling throughout the intervention, the researcher may have needed to make the connections between the uses of modeling more explicit for students. In addition, the researcher should have had the students reflect on the various forms of modeling and different ways of conducting modeling from the perspective of a scientist and engineer. By posttest, many of the student responses took a more engineering perspective on modeling rather than that of a scientist. This may have been because lessons 5.1, 5.2, and 5.3 were the last lessons taught. Within that grouping of lessons, students designed their school garden, critiqued each group's design, groups went back and made changes, until a final prototype was decided upon for the construction of the actual school garden. The fidelity observations demonstrated that the researcher did discuss and integrate modeling into the lessons but a greater emphasis on the application of modeling and the practice of designing could have been made during the lessons to help students fully grasp the aspect of how it applies to both disciplines of science and engineering (Schwartz, 2018; Schwartz & White, 2005). These findings echo what others have found with students' competence in modeling; for this practice to be developed it must be developed through experience (Crawford & Cullin, 2004; Schwartz, 2018; Schwartz & White, 2005; Schwartz & White, 2005). A variety of authentic experiences that demonstrate models and model use will begin to help student understanding about the depth of modeling in science and engineering (Schwartz & White, 2005). Mahr (2011) explained that students need to realize that there are differences between creating a model and using a model. These differences can be highlighted with the use of model examples and activities but as discussed with the other NOSI aspects, the connections between these examples and activities must be explicitly addressed or students may continue with their misconceptions (Akerson, Abd-El-Khalick, & Lederman, 2000; Metin & Leblebicioglu, 2015).

From these findings, the school garden intervention did change the views of a majority of treatment group students from naive to mixed or naive to informed over the course of the eight-weeks. Many of the aspects were intertwined and explicitly discussed during the lessons. This was demonstrated with students' responses over four aspects with the largest change from pretest to posttest. The garden-oriented activities during these lessons could have been a contributing factor for student understanding about inquiry. All lessons began with a guiding question, students designed investigations, in four of the five lessons students collected data, and finally in all lessons, students were asked to explain their reasoning with the use of evidence to support their claims. Those types of activities align with the process of inquiry enabling students the chance to have several authentic inquiry experiences throughout this intervention. Moreover, these lessons also align with NGSS and GSE allowing educators the ability to assess their students' knowledge about the process of inquiry and scientific practices. Another factor that may have affected the students learning was the researcher's fidelity to the lessons. Findings from the fidelity observations in conjunction with students' posttest responses confirm that treatment group students were learning and understood the process of inquiry by the end of the intervention.

treatment group post NOSI and comparison group post NOSI.

Due to the lack of classroom instructional time, the primary researcher was only given one classroom period to collect posttest surveys with the comparison group. The comparison group students who did not participate in the school garden intervention received science lessons during the same class periods as the treatment group students but in their regular science classrooms. The comparison group students were chosen because these students were being taught the same Georgia standards of excellence in science but in a more traditional classroom setting without project-based learning methods and without the use of a school garden. In addition, the students did not participant in NOSI activities with explicit instruction or reflective discussions.

The results indicate that the treatment group outperformed the comparison group across all eight items on the modified VASI, see Table 9. From these findings it can be determined that students who participated in the treatment group developed a greater understanding about the process of inquiry when compared to their peers who were taught in a Science indoor classroom setting. One noticeable difference which can be seen in the comparison group's responses for the aspect *begins with a question* are in reverse of what the treatment group displayed at time of pretest. The majority of the class (50%) displayed naive views. It should be reiterated that students from both groups were learning material set by state and national standards. However, the two groups did have different Science teachers all year: Treatment group = Hurley and Comparison group = Edwards. It may be the case that Mrs. Hurley's teaching is impacting her students in addition to the school garden intervention.

Findings demonstrate the *comparison group's posttest responses* are extremely similar to the *treatment group's pretest responses*, see Tables 12 and 13. This aligns with a major international NOSI study in which the majority of seventh graders around the world hold naive views about NOSI (Lederman, J., Lederman, N., Bartels, S., Jimenez, J. et al., 2019). Therefore, at this school, it was determined that a typical sixth grade student will mostly hold naive views when asked about the process of scientific inquiry. However, if these same students participated in the school garden intervention, they would have the capability of changing their views to more mixed and informed, as demonstrated with the results from the treatment group posttest responses.

comparison to other NOSI studies.

As discussed in Chapter Two, the specific framework for knowledge about inquiry is based on the NOSI framework developed by Lederman et al (2014). This framework aligns with the VASI instrument. Due to the novelty of this framework and instrument, there have been a recent influx of studies investigating students' understanding about NOSI. When comparing this population of urban sixth grade students to other VASI studies some notable similarities and differences occurred. Table 16 below, displays the various studies and the level of understanding for each aspect.

Table 13. *The most recent VASI studies results across all eight NOSI aspects including students from this study. Students from this study are in bold.*

		Aspects							
NOSI study	School grade	Multiple methods	Begins with a question	Same procedure may not same result	Procedures influence conclusion	Data not same as evidence	Procedures guided by the question	Conclusions consistent with data	Explanations Developed from data
Hamed, Jimenez, & Lederman, 2017	7th	N	N	N	N	N	N	N	N
Liu, Liu, & Guo, 2017	7th	M	M	N	M	M	I	M	M
Lederman, J., Lederman, N., Bartels, S., Jimenez, J. et al., 2019	7th	N	N	N	N	N	N	N	N
Comparison group posttest	**6th**	**N**	**N**	**N**	**N**	**N**	**N**	**I**	**N**
Treatment group pretest	**6th**	**N**	**M**	**N**	**M**	**N**	**N**	**I**	**N**
Treatment group posttest	**6th**	**M**	**M**	**M**	**M**	**I**	**M**	**I**	**M**
Yang, Park, Shin, & Lim, 2017	10th	N	M	I	M	M	M	I	N
Anggraeni, Adisendjaja, & Amprasto, 2017	11th	M	M	I	I	N	N	N	M
Leblebicioğlu, Çapkınoğlu, Metin, & Schwartz, 2017	11th	M	M	N	N	M	I	I	I
Gaigher, Lederman, & Lederman, 2014	11th	M	I	M	M	I	I	I	M

The NOSI studies, in Table 13, were all conducted in one day, students completed surveys at one time point. The pretest views of the treatment group and the posttest views of the comparison group were extremely similar to three NOSI studies. In 2017, the researchers Hamed, Jimenez, and Lederman explored the views of sixty 7th grade students in Spain. All students demonstrated naïve understandings across all eight NOSI aspects. In the same year 166 7th grade students from Beijing China were interviewed over their nature of inquiry views. Unlike in the Spanish study, the students from China had a range in their understanding about inquiry. Students carried informed views across aspects: *scientific investigations all begin with a question but do not necessarily test a hypothesis, inquiry procedures are guided by the question asked,* and *research conclusions must be consistent with the data collected.* More mixed views were demonstrated over aspects: *there is no single set and sequence of steps followed in all scientific investigations (i.e., there is no single scientific method, inquiry procedures can influence the conclusions, and scientific data are not the same as scientific evidence*. And then naive views over aspects *all scientists performing the same procedures may not get the same conclusions* and *explanations and models are developed from a combination of collected data and what is already known* (Liu, Liu, & Guo, 2017). However, the most recent NOSI study across the world with nineteen countries does indicate that the majority of 7th graders around the world do hold naive views about scientific inquiry (Lederman, Lederman, Bartels, Jimenez, et al., 2019). Therefore, these urban sixth graders from this dissertation study do perform at the same level as the majority of other middle schoolers around the world meaning that all of these students could benefit in the participation of a school garden intervention.

The VASI assessment was also conducted with four groups of high schoolers ranging in ages fifteen to seventeen. The youngest group of high schoolers was from South Korea. A total of 282 10th grade students completed the survey and they demonstrated informed views across three aspects: *scientific investigations all begin with a question but do not necessarily test a hypothesis, all scientists performing the same procedures may not get the same conclusions,* and *research conclusions must be consistent with the data collected*. These students had difficulty with aspects, *there is no single set and sequence of steps followed in all scientific investigations (i.e., there is no single scientific method)* and *scientific data are not the same as scientific evidence*, in which students held naïve views (Yang, Park, Shin, & Lim, 2017). In another high-school study but with thirty-two 11th graders in Singapore these students demonstrated informed views across four aspects: *there is no single set and sequence of steps followed in all scientific investigations (i.e., there is no single scientific method), scientific investigations all begin with a question but do not necessarily test a hypothesis, all scientists performing the same procedures may not get the same conclusions, inquiry procedures can influence the conclusions*. But the students still held naïve views over the other four aspects (Anggraeni, Adisendjaja, & Amprasto, 2017). In Turkey sixty-nine 11th graders performed slightly better than the previous two high school studies. Students from Turkey demonstrated informed and mixed views across five of the aspects: *scientific investigations all begin with a question but do not necessarily test a hypothesis, Inquiry procedures are guided by the question asked, research conclusions must be consistent with the data collected, scientific data are not the same as scientific evidence, explanations and models are developed from a combination of collected data and what is already known*. But on three of the aspects these highschoolers demonstrated naive understandings (Leblebicioğlu, Çapkınoğlu, Metin, & Schwartz, 2017). However, in one high school study with 105 11th graders from seven different high schools in South Africa, the majority of students demonstrated informed or mixed views across all eight of the NOSI aspects (Gaigher, Lederman, & Lederman, 2014). In reality, the responses from these students in South Africa are extremely similar to the posttest responses of the treatment group; achieved after explicit instruction and activities that align with NOSI. But this may be the case because the science curriculum in South Africa supports more student thinking associated with NOSI (Gaigher, Lederman, & Lederman, 2014).

Across the various NOSI studies with high school populations, these students do show more informed views when compared to the pretest scores of students in this dissertation or in other studies with younger-aged students which employed the VASI. The high schoolers in these studies outperformed the urban middle schoolers when looking at pretest views for the treatment group and posttest views for the comparison group. These older students may hold a better understanding simply due to their grade level because they are exposed to more science content in general than in middle school. But by posttest, students in the school garden intervention begin to display views that were more typical of older students such as the Korean tenth graders, the Turkish 11th graders, or the Singaporean 11th graders (Anggraeni, Adisendjaja, & Amprasto, 2017; Leblebicioğlu, Çapkınoğlu, Metin, & Schwartz, 2017; Yang, Park, Shin, & Lim, 2017). Nevertheless, the posttest views by the treatment group were even more similar to the students from South Africa, which has a national curriculum that aligns with NOSI (Gaigher, Lederman, & Lederman, 2014). This indicates that with a curriculum, i.e., structured inquiry activities, and where explicit connections between the NOSI aspects and the activities are discussed, can enhance a typical middle schooler's understanding about the process of inquiry to the level of understanding of a high schooler. This intervention showed how younger students do have the ability to learn NOSI and develop a deeper understanding about inquiry.

science camp studies.

In reality after comparing various NOSI studies, four recent studies stood out as the most comparable studies to this dissertation. It became evident that the school garden intervention is more similar to the four science summer camp studies discussed in chapter two rather than more prominent classroom NOSI studies, see Table 14. These four science summer camp studies were held over a one- to two-week period where students participated in different types of inquiry activities (Antink-Meyer, Bartos, Lederman, & Lederman, 2016; Leblebicioglu, et al 2017; Leblebicioglu, Metin, Capkinoglu, Cetin, Dogan, & Schwartz, 2017; Metin & Leblebicioglu, 2015).

Table 14. *VASI studies where students were exposed to an intervention including students from this study. Students from this study are in bold. Leblebicioglu, et al 2017* did not use all the same items as the other studies on this chart. Also, two camp sessions in this study.*

		Aspects							
Camp Study	School grade	Multiple methods	Begins with a question	Same procedure may not same result	Procedures influence conclusion	Data not same as evidence	Procedures guided by the question	Conclusions consistent with data	Explanations Developed from data
Antink-Meyer, Bartos, Lederman, & Lederman, 2014	7^{th}	Pre N Post M	Pre N Post I	Pre M Post M	Pre M Post M	Pre M Post I	Pre M Post I	Pre I Post I	Pre M Post I
Leblebicioglu, et al 2017	7^{th}	Pre N Post I Pre M Post M	Pre N Post I Pre N Post N	Pre N Post N Pre N Post N	N/A	Pre M Post I Pre M Post I	N/A	N/A	Pre M Post I Pre M Post M
Leblebicioglu, Metin, Capkinoglu, Cetin, Dogan, & Schwartz, 2017 *	7th	Pre M Post I	Pre M Post I	Pre N Post I	Pre M Post I	Pre M Post I	Pre M Post I	Pre M Post I	Pre M Post I
Treatment Group	**6th**	**Pre N** **Post M**	**Pre M** **Post M**	**Pre N** **Post M**	**Pre M** **Post M**	**Pre N** **Post I**	**Pre N** **Post M**	**Pre M** **Post I**	**Pre N** **Post M**
Comparison Group	**6th**	**Post N**	**Post N**	**Post N**	**Post N**	**Post N**	**Post N**	**Post I**	**Post N**

Comparison of the four science-summer camp studies indicated that Turkish students and Taiwanese students in science camps demonstrated less naive views than the students in this dissertation during pretest views. However, by posttest all students across the science-summer camps and the school garden intervention demonstrated improvement over the eight NOSI aspects. In particular, the Turkish and Taiwanese students had posttest views similar to those of the school garden intervention students. All three groups of students demonstrated significant change over the following three aspects: *scientific investigations begin with a question, there are multiple methods to investigations, and there are differences between data and evidence (*Antink-Meyer, Bartos, Lederman, & Lederman, 2016; Leblebicioglu, et al 2017; Leblebicioglu, Metin, Capkinoglu, Cetin, Dogan, & Schwartz, 2017). Nevertheless, as displayed in the school garden intervention, not all NOSI aspects were fully understood by the science camp participants. The aspect "*all scientist performing the same procedures may not get the same results*" did change slightly with students in the camps and the intervention, however the students still had difficulty explaining the rationale behind their answer. Also, although the NOSI *aspect "research conclusions must be consistent with the data collected"* displayed the highest understanding at the beginning of the studies, by the end of the interventions, students demonstrated further development in the understanding behind this aspect (Antink-Meyer, Bartos, Lederman, & Lederman, 2016; Leblebicioglu, et al 2017; Leblebicioglu, Metin, Capkinoglu, Cetin, Dogan, & Schwartz, 2017).

Summer science camp studies were more similar to this dissertation than other NOSI studies due to several features, including less time constraints, activities were not graded as in school but graded on student understanding, all activities were inquiry-based and aligned with

NOSI aspects, and students were immersed in an authentic setting in which they could make associations. The factor of time is always a constraint but, in this intervention, students were in block scheduling and were in each class for one and a half hours. This type of scheduling allowed the instructors the flexibility to go back and clarify concepts and ideas with students. Also, due to less time constraints, students did not feel rushed which allowed students to work through the inquiry process more slowly. As in the science camps, the student's work from the school garden intervention, i.e., their worksheets, designs, and etc. are not tied to a letter grade. This disconnect between work and grades could also be a factor as to why students in the treatment group appeared to be more similar to the science camp students.

The activities across all camps and the school garden were inquiry-based allowing the students to have agency over choices (Lederman, N., & Abd-El-Khalick, F. (1998). Furthermore, the activities were imbedded in content that was applicable to the student, i.e., ecosystems in the science camps or soil in the school garden (Abd-El-Khalick, 2002). Activities in the science camps, as with the school-garden intervention, were engaging and relevant to the students. Students could immediately relate to the activities rather than performing labs or tasks that were difficult for the students to associate with. In addition, by using activities within the science camp setting or school garden setting, the students were engaging in more authentic science (Crawford, 2012). Students were working with real tools and collecting their own data. They were actually working through the same process of inquiry that professional scientists and engineers do. But as expressed by Khishfe & Abd-El-Khalick (2002), if these activities and out-of-classroom settings were not explicitly discussed with students and how they were all connected, students would be unable to construct new knowledge. Students needed explicit instruction as well as time to reflect on what they were learning from performing these activities. Both of these approaches were seen in the science camps and the school garden intervention which inevitably may have been how students were able to reach mixed to informed understanding in a short amount of time. It was this authentic setting, in conjunction with aligned activities and explicit instruction, which helped promote change in the students' understanding about NOSI (Smith, Maclin, Houghton, & Hennessey, 2000).

Scientific Practices

Understanding NOSI was only part the problem, students also needed to be able to apply the knowledge gained through inquiry to their scientific practices. The second research question asked: How are students' application of scientific practices affected by participation in a school garden intervention? To answer this question, students filled out the quantitative assessment created by combining items from Project2061 (AAAS, 1990), a multiple-choice assessment which included eight items over two practices: control of variables strategy and modeling.

treatment group changes.

A total of eight multiple choice items were given to students. Five items assessed control of variables strategy (CVS) and three items were over modeling. Students had to apply their knowledge about inquiry in these questions. The treatment group demonstrated over a one-point gain from pretest (M = 2.391, SD = 1.325) to posttest (M = 3.489, SD = 1.692.). Due to this change in test scores, a statistical test, independent samples t-test, showed that significant learning did occur from pretest to posttest, see chapter 4. Additionally, the effect size of the intervention was also calculated to better understand the magnitude of the intervention on the participating students. The effect size for the treatment group was found to be Cohen's d = .681, which indicates that the intervention had a high moderate effect on the treatment group students from pretest to posttest (Cohen, 1988; Fritz, Morris, & Richler, 2011). From these findings, the students in this group were able to change their understanding behind CVS and modeling. Nonetheless, the mean scores at both pretest and posttest do not show a passing score. This may appear disconcerting because the students never reached a passing score yet for this study a passing score was not the intent. Instead this study wanted to show gains in student learning and from pretest to posttest the treatment group students did demonstrate gains in their learning about science practices.

control of variables strategy (CVS).

Students were first exposed to CVS in lesson 2 where students were designing and conducting observational investigations. Lessons 3.1 and 3.2 dove deeper into this practice by having groups design and conduct an experimental investigation with water and another investigation with the planting of a Fast Plant. In these lessons, groups noted which variables they used and why a variable was chosen. In addition, the researcher stressed the use of variables with the students in lessons 3.1 and 3.2. At the end of those lessons the researcher brought the class together and had all of the groups write their data on the board. Then, as a class, they discussed which variables each group used and any commonalities or differences between the groups' choice of variables. Throughout the lessons, the researcher posed hypothetical questions to the class, *asking what would happen if we changed the garden to this type of soil, or what would happen if we only used this amount of water, or do we have good data if we change two variables at once?* It was in these class discussions where the researcher could explicitly make connections for the students between what they were doing in the lesson and how it would affect their school garden outside. By lesson 5.3, when students began to construct the garden outside, the students were again reminded how variables work with one another. The variables they learned about during the lesson, included type of soil, amount of water, or type of plant and their role in the larger school garden.

modeling.

Modeling was the other assessed science practice. Modeling is important in both fields of science and engineering because this practice teaches students that models are not simply visual representations. Rather, models can help explain phenomena or where a problem is located. During the intervention, students had two different authentic experiences with modeling. In lesson 3.2, students created their indoor garden, a miniature representation of the garden the students would create at the end of the intervention. This miniature garden allowed students to try different soils and amounts of water to better understand what they would need to do once it was time to move outside to the full-size school garden. In lessons 5.1, 5.2, and 5.3, students began to understand modeling but from a more engineering perspective. In these lessons, groups were designing what they thought would be the best class garden to construct. But designing was only the beginning. The groups received critiques from one another, helping students understand that in design several iterations of the model or prototype are created before a final model or prototype is selected. By the end of the intervention, students experienced modeling by creating a miniature garden and trying different variables with the indoor garden as well as designing and then constructing the final design of their school garden. Overall, the students had many authentic moments throughout this intervention where they could actually apply the practices that they were learning but as indicated with their less than 50% achievement scores on their posttest more explicit instruction is needed to further help students understand the connection between what they are physically and mentally doing during an investigation and how this *doing* is actual a scientific practice.

treatment group and comparison group.

The comparison group did better on items 2 and 6; not huge differences but they did out score the treatment group, see Table 15. However, across the other six multiple choice items, the treatment group outperformed the comparison group. When analyzing total posttest scores for this multiple-choice assessment, the treatment group scored one point higher than the comparison group. That was a significant difference. Due to these differences, statistical tests were conducted to better understand if the intervention affected the students. The statistical tests did indicate that students who participated in the treatment would receive higher scores on their multiple-choice posttest assessment. Additionally, effect size was also calculated to better understand the impact of intervention on both groups without the challenge of sample size. The effect size was found to be, Cohen's *d* = .9231, between both groups indicating that the intervention largely impacted the students who were participating in the treatment group (Cohen, 1988; Fern & Monroe, 1996; Fritz, Morris, & Richler, 2011). Note that the comparison group did not have the same project-based learning curriculum or as many experiences to work through investigations where they would have had the ability to perform these practices.

As with the VASI assessment, the comparison group's posttest answers were similar to those of the treatment group pretest answers, see Tables 12 and 14. This indicated that both groups had a similar understanding about inquiry and scientific practices but, as demonstrated with the treatment group posttest scores, the treatment group students were learning throughout the school garden intervention where the combination of curriculum, pedagogical approaches, and out-of-classroom setting all enabled the development of a more informed view about inquiry and the application of science practices.

students and the intervention.

This dissertation began as a study to investigate how students understand NOSI and the application of science practices. These two constructs were investigated because they can help further an individual's scientific literacy.

A review of the literature over inquiry and science practices showed classroom settings as the environment where the majority of these studies are conducted. But school science is becoming far too compartmentalized for students to relate it to events in everyday life (Adams, Gupta, & DeFelice, 2012; Braund & Reiss, 2006). A way to combat this is to place students in an out-of-classroom setting, e.g., a school-garden, where students have a more authentic experience with the curriculum (Rennie, 2007; 2014). These settings create a space for more situated learning. Situated learning allows students to be immersed in a setting. To further the situated learning experience, instructors can use problem-based or project-based learning as seen in this school-garden intervention. The school garden intervention does support the need for inquiry activities to be tied to NGSS standards and NOSI aspects (LeadStates, 2013; Lederman and Abd-El-Khalick, 1998). The content should be imbedded within the activities but that is not enough; it cannot be assumed that students will implicitly learn the content (Abd-El-Khalick, 2002; Khishfe & Abd-El-Khalick, 2002). Instead activities need to be explicit and reflective. As shown with NOS, NOSI and NGSS standards must also be taught explicitly with reflection; instructors cannot assume students will understand the material at the necessary level (Akerson, Abd-El-Khalick, & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002). During the intervention activities and their connections to NOSI and NGSS were explicitly discussed by the researcher, allowing for student understanding to develop throughout the intervention.

Boys and girls both learned when participating in the intervention. This finding indicates that activities and instruction affected both gender's learning in a positive manner. The literature discusses how girls lose interest in STEM when attending school (Brickhouse, Lowery & Schultz, 2000). A school garden setting may be an avenue to keep girls interested in the STEM pipeline. In addition, within this population of all minority urban students, many did not enjoy going outside or know what it meant to garden. Over time the students began to enjoy the intervention by interacting with plants and completing inquiry lessons about the school garden. Slowly students began to ask for more time outside; students wanted to work in the school garden. Currently many urban students do not have an understanding about nature or how they relate to it (Lekies, Yost, & Rode, 2015; Louv, 2008). Again, the school garden setting may be another avenue to help students develop a relationship with nature and the environment. This deeper understanding about the environment could impact how these students make future decisions about environmental topics such as climate change and fresh water.

This intervention demonstrated to be useful in facilitating change in students understanding of inquiry and science practices. The school garden intervention kept students in constant engagement and formative assessment aligning with inquiry content; it immersed the students in the entire process. Furthermore, the tools of assessment used in this study demonstrated to be reliable with this unique population of urban middle schoolers. The VASI instrument clearly helped identify the various categories of understanding about NOSI which an individual may hold (Lederman et al, 2014). While the items from Project 2061 explored students' understanding of the application of a science practice (AAAS, 1993). In the end, this school garden intervention provided insights on how out-of-classroom settings can be an envelopment to help students develop an understanding about the NOSI and how new knowledge can be created from this process.

Implications

Given the significant numbers of students in indoor classrooms around the nation, an understanding of how to improve understanding behind the process of inquiry and the application of science practices in such out-of-school settings is important. This dissertation provides insight into the extent that it is necessary to provided consistent engagement with NOSI and science practices as the content of focus. Only the aspects of NOSI and science practices that were embedded and explicitly discussed throughout multiple school garden lessons were areas with demonstrated improved understanding and application from pretest to posttest.

The school garden intervention proved to be an avenue where out-of-classroom learning can occur. However, this intervention also supported many previous findings discussed in the fields of science education: explicit instruction (Khishfe & Abd-El-Khalick, 2002), inquiry activities (Abd-El-Khalick, 2002), and authentic experiences (Crawford, 2012) all play a role in how a student learns science. Within this authentic experience, students still have structured learning. The difference is that the structure comes from the alignment of the content with the out-of-classroom setting. The content and setting allow students the ability of repeated exercise in the application of science practices. It is this repeated exposure within the authentic experience that enables students to better understand NOSI (Crawford, 2012).

Furthermore, the data from this study show that tentative and subjectiveness were difficult aspects for students to completely understand. Perhaps NOS could be added to a NOSI unit. Not only would this give students more exposure to the aspect of tentativeness/subjectiveness but it will also help students in being better inquiry learners. By combing specific aspects of NOS with specific aspects of NOSI could benefit the student in more ways than one.

The summer science camp studies related more to the type of work found in this dissertation (Antink-Meyer, Bartos, Lederman, & Lederman, 2016; Leblebicioglu, et al 2017; Leblebicioglu, Metin, Capkinoglu, Cetin, Dogan, & Schwartz, 2017; Metin & Leblebicioglu, 2015). It may have been due to the fact that the science camps and school-garden were over longer periods of time, allowing the students and instructors more time to process the activities. Students' work is not linked to a grade, which may influence students to try more risky answers because they understand their grade will not be affected. And the environment between the science camps and school garden is engaging and authentic. These details might be enough to motivate students in learning more science.

The most surprising find from this dissertation is how technology and media may actually be hindering students understanding about Science. Similar findings were found in other technology studies (Krajcik, & Mun, 2014; Szu, Osborne, & Patterson, 2017). The responses from the students in this school garden intervention indicate that researchers and educators need to take a more in-depth look at how technology and media are influencing the current generation of students.

Conclusions

In today's world of education, the term scientific literacy is being discussed across several agencies (NRC, 2012; AAAS). Scientific literacy is an individual's ability to understand the natural world as well as skills or practices that enable the ability to understand the natural world (Roberts, 2007; Roberts & Bybee, 2014). This notion of scientific literacy can be viewed as how an individual comprehends natural phenomena that occur in everyday life, e.g., the sun rising, the color of the sky, why things fall to the ground, etc. With more scientific literacy, an individual can become a better problem solver and consumer of science. In this dissertation, scientific literacy was divided into how an individual understands the process of scientific inquiry, NOSI, and how an individual understands the application of science practices, NGSS.

The objective of this dissertation was to introduce NOSI aspects and NGSS science practices through scientific inquiry in a school garden and to make aspects and practices explicit throughout the context of the intervention. Based on the research findings, it was concluded that the school garden intervention was effective for introducing six of the eight NOSI aspects: *scientific investigations all begin with a question but do not necessarily test a hypothesis, there is no single set and sequence of steps followed in all scientific investigations (i.e., there is no single scientific method), inquiry procedures are guided by the question asked; questions drive the process, all scientists performing the same procedures may not get the same conclusions, research conclusions must be consistent with the data collected,* and *scientific data are not the same as scientific evidence.* For two of the aspects, *"inquiry procedures can influence the conclusions"* and *"explanations and models are developed from a combination of collected data and what is already known"* change did occur in the students' views but not to the same extent as the other NOSI aspects. The two science practices of modeling and control of variables were also found to be improved after the school garden intervention.

The duration of the school garden intervention was long and intensive. The intervention was conducted during school hours during the science period. The students were placed in the intervention; there was no voluntary participation. However, the majority of the students appeared highly motivated, relaxed, and in an enjoyable atmosphere. Most school garden research reported in the literature was focused on a specific subject but this school garden intervention was interdisciplinary and conducted in a natural out-of-classroom setting. There are few studies investigating inquiry in an out-of-classroom setting. In this intervention, students were exposed to five garden lessons. These lessons allowed students to discuss what types of investigations they designed, the data they collected, and the explanations they could conclude. These features added authenticity and agency to the school garden experience. Students throughout the intervention were guided to make connections between the lessons NOSI aspects and NGSS practices. Such explicit and purposeful attempts supported the students of NOSI and practices in this out-of-classroom context, resulting in positive results in a moderate amount of time.

Helping middle school students develop an understanding of NOSI aspects and NGSS practices needs time and deliberate effort. The researcher did not expect all students to develop an informed understanding about inquiry and practices, but the researcher hoped to identify which features from a school garden intervention could help the development of NOSI and practices. Furthermore, all activities were inquiry based and allowed students time to reflect on what they were doing in the activities and how these activities relate to professional scientists and engineers. This intervention was engaging, relevant, and an authentic context to developing the eight NOSI aspects and NGSS practices.

Retention of learning was a concern, but the same posttest could not be given to the treatment group students the following year. This study has implications for science and engineering education. Throughout the intervention, explicit instruction was used when discussing NOSI and science practices. NOSI research exposed how implicit instruction over inquiry and practices do not develop adequate and meaningful NOSI and practices conceptions. Instead, a greater emphasis on explicit instruction over NOSI aspects and practices in the context of inquiry activities should be made throughout K-16 science education.

Limitations

Due to the nature of working in public school with students and teachers, challenges always occur. Many of these challenges became limitations in this dissertation. These were mitigated by the fact that the primary researcher of this investigation is also the instructor of the treatment group students. This may have created some researcher biases during the investigation.

Small sample size was another challenge. Again, because the researcher conducted this study during normal school hours during the students' science class period, the researcher was taking instructional time away from the sixth-grade teachers which eludes to taking time away from practicing for the science standards of the state of Georgia. The researcher was only able to work with one out of the four sixth grade teams found in this public middle school. Another limitation was not directly linking the assignments from the school garden intervention to the students' grades in the course. Students in the treatment group did receive completion grades for the group work and worksheets completed in class. Also, students in the treatment group were never given homework; it may have benefited the researcher to incorporate other assessments throughout the intervention. The last limitation is transfer of knowledge. The researcher did not ask for the ability to analyze students' science grades at the end of the semester, eight weeks after the end of the intervention or to collect students' standardized tests scores. Gaining access to those types of scores may help demonstrate if an intervention of this nature can affect students' weeks or semesters after the initial participation.

Future Research

This school garden intervention dissertation is only the beginning for this area of research. Several future projects and studies can be developed from this dissertation. A practical study would be to longitudinal follow the students who participated in the school garden intervention to determine if their same views about the NOSI and the application of scientific practices holds over time or how fast learning decays. This longitudinal investigation could be done after an initial semester or a year after participation in the school garden intervention.

From a data perspective, future work could investigate the student interviews. This difficultly of interviewing younger students over their understanding about inquiry could be a new study on its own. Additionally, it would be interesting to conduct a study with students from older grade levels to investigate if the school garden intervention affects their learning about NOSI and practices at the same magnitude as the sixth graders in this study.

Switching from future work with students to future work with teachers and instructors, the next natural progression of this intervention would be to have teachers instruct the lessons and have the researcher evaluate these teachers on their fidelity to the lessons. By doing so, the researcher could determine how effective the curriculum is and would confirm if the school garden lessons are ready for publication, allowing any instructor or teacher the ability to pick up these lessons and immediately begin instructing to their students. Another study would investigate how teachers understand NOSI and science practices and how this understanding is necessary for effective teaching in this way, an informal setting e.g. school garden. What professional development is needed for teachers to effectively teach in an informal setting such as a school garden? What other resources or supports do teachers need?

As discussed in this dissertation the areas of school garden research and the process of inquiry are largely unexplored, leaving many research opportunities for future discoveries in science education and the learning sciences.

REFERENCES

Abd-El-Khalick, F. (2002). Rutherford's enlarged: A content-embedded activity to teach about nature of science. *Physics Education*, *37*(1), 64.

Adams, J. D., Gupta, P., & DeFelice, A. (2012). Schools and informal science settings: collaborate, co-exist, or assimilate? *Cultural Studies of Science Education*, *7*(2), 409–416. doi:10.1007/s11422-012-9399-x

Aguilar, O. M., Waliczek, T. M., & Zajicek, J. M. (2008). Growing environmental stewards: The overall effect of a school gardening program on environmental attitudes and environmental locus of control of different demographic groups of elementary school children. *HortTechnology*, *18*(2), 243-249.

Akerson, V. L., Abd-El-Khalick, F., & Lederman, N. G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *37*(4), 295-317.

American Association for the Advancement of Science. (1990). Project 2061: *Science for all Americans*. New York: Oxford University Press.

Anderson, J. R., Reder, L. M., Simon, H. A. (1997) Situative versus cognitive perspectives: From versus substance. *Educational Researcher*, 26(1), 18-21.

Anggraeni, N., Adisendjaja, Y. H., & Amprasto, A. (2017, September). Profile of high school students' understanding of scientific inquiry. In *Journal of Physics: Conference Series* (Vol. 895, No. 1, p. 012138). IOP Publishing.

Antink-Meyer, A., Bartos, S., Lederman, J. S., & Lederman, N. G. (2016). USING SCIENCE CAMPS TO DEVELOP UNDERSTANDINGS ABOUT SCIENTIFIC INQUIRY—TAIWANESE STUDENTS IN A US SUMMER SCIENCE CAMP. *International Journal of Science and Mathematics Education*, *14*(1), 29-53.

Arnseth, H. C. (2008). Activity theory and situated learning theory: contrasting views of educational practice. *Pedagogy, Culture & Society*, *16*(3), 289-302.

AAAS Science Assessment. (2018). Retrieved December 18, 2017, from http://assessment.aaas.org/topics

Bakker, M., & Wicherts, J. M. (2014). Outlier removal, sum scores, and the inflation of the type I error rate in independent samples t tests: The power of alternatives and recommendations. *Psychological methods*, *19*(3), 409.

Barnard, G. A. (1984). Comparing the means of two independent samples. *Journal of the Royal Statistical Society: Series C (Applied Statistics)*, *33*(3), 266-271.

Barron, B. J., Schwartz, D. L., Vye, N. J., Moore, A., Petrosino, A., Zech, L., & Bransford, J. D. (1998). Doing with understanding: Lessons from research on problem-and project-based learning. *Journal of the Learning Sciences*, *7*(3-4), 271-311.

Beckman, L. L., & Smith, C. (2008). An Evaluation of Inner-City Youth Garden Program Participants' Dietary Behavior and Garden and Nutrition Knowledge. *Journal of Agricultural Education*, *49*(4), 11-24.

Beichner, R. J., Saul, J. M., Abbott, D. S., Morse, J. J., Deardorff, D., Allain, R. J., & Risley, J. S. (2007). The student-centered activities for large enrollment undergraduate programs (SCALE-UP) project. *Research-based reform of university physics*, *1*(1), 2-39.

Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House*, *83*(2), 39-43.

Bell, J., Falk, J., Hughes, R., Hunt, G., Parrish, J., Ruffin, M., & Troxel, G. (2016). Informal STEM Education: Resources for Outreach, Engagement and Broader Impacts. *Science Education (CAISE)*.

Bell, R. L., Lederman, N. G., & Abd-El-Khalick, F. (2000). Developing and acting upon one's conception of the nature of science: A follow-up study. *Journal of research in science teaching*, *37*(6), 563-581.

Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. A. (Eds.), (2009). *Learning science in informal environments*. National Academies Press.

Bell, P., Tzou, C., Bricker, L. A., & Baines, A. D. (2012). Learning in diversities of structures of social practice: Accounting for how, why and where people learn science. *Human Development*, 55, 269–284.

Bevan, B., Gutwill, Joushua P., Petrich, M., & Wilkinson, K. (2010). Learning Through STEM-Rich Tinkering: Findings From a Jointly Negotiated Research Project Taken Up in Practice. *Science Education*, *99*(1), 98–120.

Billett, S. (1996). Situated learning: Bridging sociocultural and cognitive theorising. *Learning and instruction*, *6*(3), 263-280.

Blair, D. (2009). The child in the garden: An evaluative review of the benefits of school gardening. *The Journal of Environmental Education*, *40*(2), 15-38.

Blair, R. C., & Higgins, J. J. (1985). Comparison of the power of the paired samples t test to that of Wilcoxon's signed-ranks test under various population shapes. *Psychological Bulletin*, *97*(1), 119.

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational psychologist*, *26*(3-4), 369-398.

Boneau, C. A. (1960). The effects of violations of assumptions underlying the t test. *Psychological bulletin*, *57*(1), 49-64.

Bransford, J.D., Sherwood, R.D., Hasselbring, T.S., Kinzer, C.K., & Williams, S.M. (1990). Anchored instruction: Why we need it and how technology can help. In D. Nix & IL Spiro (Eds.), Cognition, education and multimedia: Exploring ideas in high technology (pp. 115--141). Hillsdale, NJ: Lawrence Erlbaum.

Bransford, J., Stevens, R., Schwartz, D., Meltzoff, A., Pea, R., Roschelle, J., Vye, N., Kuhl, P., Bell, P., Barron, B., Reeves, B., & Sabelli, N. (2006). Learning theories and education: Toward a decade of synergy. In: P. A. Alexander & P. H. Winne (Eds.), *Handbook of educational psychology*. Second edition (pp. 209–244). Mahwah, NJ: Lawrence Erlbaum Associates.

Braund, M., & Reiss, M. (2006). Towards a more authentic science curriculum: The contribution of out-of-school learning. *International Journal of Science Education*, *28*(12), 1373-1388.

Brickhouse, N. W., Lowery, P., & Schultz, K. (2000). What kind of a girl does science? The construction of school science identities. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *37*(5), 441-458.

Brooks, D. C. (2011). Space matters: The impact of formal learning environments on student learning: Impact of formal learning environments on student learning. *British Journal of*

Educational Technology, *42*(5), 719–726. doi:10.1111/j.1467-8535.2010.01098.x

Brossard, D., & Scheufele, D. A. (2013). Science, new media, and the pub-lic. *Science*, *339*(6115), 40-41.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learn-ing. *Educational researcher*, *18*(1), 32-42.

Bybee, R. W. (2004). Scientific Inquiry and Science Teaching. In: Flick, L. B., & Lederman, N. G., (eds) *Scientific Inquiry and Nature of Science. Implications for teaching, learning, and teacher education*, 1(25). Springer, Dordrecht

Callahan, M. A. (2012). Conducting Cognitive Developmental Research in Museums: Theoreti-cal Issues and Practical Considerations. *Journal of Cognition and Development*, *13*(2), 137–151. doi:10.1080/15248372.2012.666730

Capon, N., & Kuhn, D. (2004). What's so good about problem-based learning?. *Cognition and Instruction*, *22*(1), 61-79.

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.

Carey, S., Evans, R., Honda, M., Jay, E., & Unger, C. (1989). 'An experiment is when you try it and see if it works': a study of grade 7 students' understanding of the construction of sci-entific knowledge. *International Journal of Science Education*, *11*(5), 514-529.

Chen, Y. C., Hand, B., & Park, S. (2016). Examining elementary students' development of oral and written argumentation practices through argument-Based Inquiry. *Science & Educa-tion*, *25*(3-4), 277-320.

Chen, Z., & Klahr, D. (1999). All other things being equal: Acquisition and transfer of the con-trol of variables strategy. *Child Development*, 1098-1120.

Chen, Z., & Siegler, R. S. (2000). II. Overlapping Waves Theory. *Monographs of the Society for Research in Child Development*, *65*(2), 7–11. doi:10.1111/1540-5834.00075

Chi, B., Dorph, R., & Reisman, L. (2016) Evidence & Impact: Museum-Managed STEM Programs in Out-of-School Settings.

Chinn, C. A. and Malhotra, B. A. (2002), Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education*, 86(2), 175–218. doi:10.1002/sce.10001

Choi, J. I., & Hannafin, M. (1995). Situated cognition and learning environments: Roles, structures, and implications for design. *Educational technology research and development*, *43*(2), 53-69.

Choudhury, S., Blakemore, S. J., & Charman, T. (2006). Social cognitive development during adolescence. *Social Cognitive and Affective Neuroscience*, *1*(3), 165-174.

Cobb, P., & Bowers, J. (1999). Cognitive and situated learning perspectives in theory and practice. *Educational researcher, 28*(2), 4-15.

Cobb, P., Confrey, J., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher*, *32*(1), 9-13.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Earlbaum Associates.

Collins, A. (1988). Cognitive apprenticeship and instructional technology (Technical Report 6899): BBN Labs Inc. Cambridge, MA.

Collins, A., Brown, J.S., & Newman, S.E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L.B. Resnick (Ed.), Knowing, learning and instruction: Essays in honour of Robert Glaser (pp. 453-494). Hillsdale, NJ: LEA.

Cotugna, N., Manning, C. K., & DiDomenico, J. (2012). Impact of the use of produce grown in an elementary school garden on consumption of vegetables at school lunch. *Journal of hunger & environmental nutrition*, *7*(1), 11-19.

Crawford, B. A. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of research in science teaching*, *44*(4), 613-642.

Crawford, B. A. (2012). Moving the essence of inquiry into the classroom: Engaging teachers and students in authentic science. In *Issues and challenges in science education research* (pp. 25-42). Springer, Dordrecht.

Crawford, B. (2014). From inquiry to scientific practices in the science classroom. In: Lederman, N. G., & Abell, S. K. (2014). *Handbook of research on science education (Vol. II).* Abingdon, England: Routledge.

Crawford, B. A., & Cullin, M. J. (2004). Supporting prospective teachers' conceptions of modelling in science. *International Journal of Science Education*, *26*(11), 1379-1401.

Creswell, J.W. (2005). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (2nd ed.). Upper Saddle River, NJ: Merrill/Prentice Hall.

Creswell, J. W., & Clark, V. L. P. (2017). *Designing and conducting mixed methods research*. Sage publications.

Creswell, J.W., & Plano Clark, V.L. (2011). *Designing and conducting mixed methods research* (2nd ed.). Los Angeles, CA: Sage.

Crowley, K., & Knutson, K. (2007). The need for a practical theory of museum learning. Paper presented at the workshop “Learning in Museums—The Role of Media” at the Knowledge Media Research Center, Tubingen, Germany.

Cutter-Mackenzie, A. (2009). Multicultural School Gardens: Creating Engaging Garden Spaces in Learning about Language, Culture, and Environment. *Canadian Journal of Environmental Education*, *14*(1), 122-135.

Dean Jr., D., & Kuhn, D. (2007). Direct instruction vs. discovery: The long view. *Science Education*, *91*(3), 384–397. doi:10.1002/sce.20194

DeFillippi, R. J. (2001). Introduction: Project-based learning, reflective practices and learning.

Dekalb County Schools (2016). Champion Middle School. Retrieved from http://www.championms.dekalb.k12.ga.us/

Dewey, J. (1912). Perception and organic action. *The Journal of Philosophy, Psychology and Scientific Methods*, *9*(24), 645-668.

Dewey, J. (1938). Experience and Education New York. *Touchstone*, *18*.

Dewey, J. (1917). The need for social psychology. *Psychological Review*, *24*(4), 266.

Dewey, J. (2007). *Experience and education*. Simon and Schuster.

DeWitt, J., & Osborne, J. (2007). Supporting Teachers on Science focused School Trips: Towards an integrated framework of theory and practice. *International Journal of Science Education*, *29*(6), 685–710. doi:10.1080/09500690600802254

Dilli, R. (2016). Conducting Museum Education Activities within the Context of Developing a Nature Culture in Primary School Students: MTA Natural History Museum Example. *International Journal of Environmental and Science Education*, *11*(2), 75-84.

Dunbar, K. (2000). How Scientists Think in the Real World. *Journal of Applied Developmental Psychology, 21*(1), 49-58.

Eastwood, J. L., Sadler, T. D., Zeidler, D. L., Lewis, A., Amiri, L., & Applebaum, S. (2012). Contextualizing nature of science instruction in socioscientific issues. *International Journal of Science Education*, *34*(15), 2289-2315.

Evans, A., Ranjit, N., Rutledge, R., Medina, J., Jennings, R., Smiley, A., & Hoelscher, D. (2012). Exposure to multiple components of a garden-based intervention for middle school students increases fruit and vegetable consumption. *Health promotion practice*, *13*(5), 608-616.

Falk, J. H. (2005). Free-choice environmental learning: framing the discussion. *Environmental Education Research*, *11*(3), 265-280.

Falk, J., & Storksdieck, M. (2005). Using the contextual model of learning to understand visitor learning from a science center exhibition. *Science education*, *89*(5), 744-778.

Falk, J. H., & Dierking, L. D. (2004). The contextual model of learning. *Reinventing the museum: Historical and contemporary perspectives on the paradigm shift*, 139-142.

Falk, J. H., & Dierking, L. D. (2018). *Learning from museums*. Rowman & Littlefield.

Falk, J. H., Randol, S., & Dierking, L. D. (2011). Mapping the informal science education landscape: An exploratory study. *Public Understanding of Science*. 21(7), 865 – 874.

Falk, J., & Storksdieck, M. (2005). Using the contextual model of learning to understand visitor learning from a science center exhibition. *Science education*, *89*(5), 744-778.

Falk, J. H., & Storksdieck, M. (2010). Science learning in a leisure setting. *Journal of Research in Science Teaching*, *47*(2), 194-212.

Feir-Walsh, B. J., & Toothaker, L. E. (1974). An empirical comparison of the ANOVA F-test, normal scores test and Kruskal-Wallis test under violation of assumptions. *Educational and Psychological Measurement*, *34*(4), 789-799.

Felton, M., & Kuhn, D. (2001). The development of argumentative discourse skill. *Discourse processes*, *32*(2-3), 135-153.

Fern, E. F., & Monroe, K. B. (1996). Effect-size estimates: Issues and problems in interpretation. *Journal of Consumer Research*, *23*(2), 89-105.

Filippoupoliti, A., & Koliopoulos, D. (2014). Informal and non-formal education: An outline of History of Science in museums. *Science & Education*, *23*(4), 781-791.

Fleener, A. W., Robinson, C. W., Williams, J. D., & Kraska, M. (2011). Literature in the garden curriculum effects on life skills of children. *HortTechnology*, *21*(4), 424-428.

Flick, L. B., (2004). Developing understanding of scientific inquiry in secondary students. In: Flick, L. B., & Lederman, N. G., (eds) *Scientific Inquiry and Nature of Science. Implications for teaching, learning, and teacher education,* 1(25). Springer, Dordrecht

Foreman-Peck, L., & Travers, K. (2013). What is distinctive about museum pedagogy and how can museums best support learning in schools? An action research inquiry into the practice of three regional museums. *Educational Action Research*, *21*(1), 28-41.

Fraenkel, J.R., Wallen, N.E., & Hyun, H. (2012). *How to design and evaluate research in education* (8th ed.). Boston, MA: McGraw-Hill.

Fritz, C. O., Morris, P. E., & Richler, J. J. (2012). Effect size estimates: current use, calculations, and interpretation. *Journal of experimental psychology: General*, *141*(1), 2.

Fusco, D. (2001). Creating relevant science through urban planning and gardening. *Journal of research in science teaching*, *38*(8), 860-877.

Gabrys, G., Weiner, A., & Lesgold, A. (1993). Learning by problem solving in a coached apprenticeship system. In M. Rabinowitz fed.), Cognitive science foundations of instruction (pp. 119-147). HillsdaIe, NJ: Lawrence Erlbaum Associates.

Gaskell, J. (1992). Authentic science and school science. *International Journal of Science Education*, 14:3, 265-272, DOI: 10.1080/0950069920140303

Gautreau, B. T., & Binns, I. C. (2012). Investigating Student Attitudes and Achievements in an Environmental Place-Based Inquiry in Secondary Classrooms. *International Journal of Environmental and Science Education*, *7*(2), 167-195.

Gay, L.R., Mills, G.E., & Airasian, P. (2009). *Educational research: Competencies for analysis and applications* (9th ed.). Upper Saddle River, NJ: Merrill.

Gaylie, V. (2009). *The learning garden: Ecology, teaching, and transformation*. New York: Peter Lang.

Gaylie, V. (2011). *Roots and research in urban school gardens*. New York: Peter Lang.

Georgia Standards (2016). Science Georgia Standards of Excellence (GSE). Retrieved from https://www.georgiastandards.org/Georgia-Standards/Pages/Science.aspx

Giedd, J., Stockman, M., Weddle, C., Liverpool, M., Wallace, G., Lee, N., Lalonde, F., & Lenroot, R., (2012) Anatomic Magnetic Resonance Imaging of the Developing Child and Adolescent Brain. In Reyna, V. F., Chapman, S. B., Dougherty, M. R., & Confrey, J. E. (Eds.), *The adolescent brain: Learning, reasoning, and decision making* (pp. 15- 35). American Psychological Association.

Gillespie, K. L., & Melber, L. M. (2014). Connecting students around the world through a collaborative museum education program. *Journal of Museum Education, 39*(1), 108-120.

Graham, H., Beall, D. L., Lussier, M., McLaughlin, P., & Zidenberg-Cherr, S. (2005). Use of school gardens in academic instruction. *Journal of Nutrition Education and behavior*, *37*(3), 147-151.

Greeno, J. G. (1997). On claims that answer the wrong questions. *Educational Researcher*, 26(1), 5-17.

Griffin, M.M. (1995). You can't get there from here: Situated learning, transfer and map skills. Contemporary Educational Psychology, 20, 65-87.

Groeneveld, R. A., & Meeden, G. (1984). Measuring skewness and kurtosis. *Journal of the Royal Statistical Society: Series D (The Statistician)*, *33*(4), 391-399.

Gutwill, J. (2006). Labels for Open-ended Exhibits: Using Questions and Suggestions to Motivate Physical Activity. *Visitor Studies Today, 9*(1), 1-9.

Gutwill, J. P., & Allen, S. (2012). Deepening students' scientific inquiry skills during a science museum field trip. *Journal of the Learning Sciences*, 21(1), 130–181.

Gwet, K. L. (2014). *Handbook of inter-rater reliability: The definitive guide to measuring the extent of agreement among raters*. Advanced Analytics, LLC.

Hamed, S., Jimenez, J., & Lederman, N. (2017, November). Scientific Inquiry Views in Spanish Middle School Students and Pre-Service Science Teachers: A Comparison. In *ESERA 2017 Conference, Dubin City University, Irelend. https://www. researchgate. net/publication/322603295*.

Harley, S. (1993). Situated learning and classroom instruction. Educational Technology, 33(3), 46-51.

Hazzard, E. L., Moreno, E., Beall, D. L., & Zidenberg-Cherr, S. (2012). An evaluation of the California instructional school garden program. *Public health nutrition*, *15*(2), 285-290.

Hodson, D. (2014). Learning Science, Learning about Science, Doing Science: Different goals demand different learning methods. *International Journal of Science Education*, 36:15, 2534-2553, DOI: 10.1080/09500693.2014.899722

Herrington, J., & Oliver, R. (2000). An instructional design framework for authentic learning environments. *Educational technology research and development*, *48*(3), 23-48.

Hirschi, J. S., & Sobel, D. (2015). *Ripe for Change: Garden-Based Learning in Schools.* Cambridge, MA: Harvard Education Press.

Hofstein, A., & Rosenfeld, S. (1996). Bridging the gap between formal and informal science learning.

Honebein, P.C., Duffy, T.M., & Fishman, B.J. (1993). Constructivism and the design of learning environments: Context and authentic activities for learning. In T.NL Duffy, J. Lowyck, & D.H. Jonassen (Eds.), Designing environments for constructive learning (pp. 87-108). Heidelberg: Springer-Verlag.

Jacobs, J. A., & Frickel, S. (2009). Interdisciplinarity: A critical assessment. *Annual review of Sociology*, 43-65.

Karsh, K., Bush, E., Hinson, J., & Blanchard, P. (2009). Integrating horticulture biology and environmental coastal issues into the middle school science curriculum. *HortTechnology*, *19*(4), 813-817.

Kavanaugh, K. (2017). Project Learning Garden: A Systematic Review of the Effectiveness of the Evaluation Techniques on School Gardens.

Khishfe, R., & Abd-El-Khalick, F. (2002). Influence of explicit and reflective versus implicit inquiry-oriented instruction on sixth graders' views of nature of science. *Journal of research in science teaching*, *39*(7), 551-578.

Kim, K. Y., & Crowley, K. (2010). Negotiating the goal of museum inquiry: How families engineer and experiment. In *Instructional Explanations in the Disciplines* (pp. 51-65). Springer US.

Kim, M., & Dopico, E. (2016). Science education through informal education. *Cultural Studies of Science Education*, *11*(2), 439-445.

Kisiel, J. F. (2014). Clarifying the complexities of school–museum interactions: Perspectives from two communities. *Journal of Research in Science Teaching*, *51*(3), 342-367.

Kisiel, J., & Anderson, D. (2010). The challenges of understanding science learning in informal environments. *Curator: The Museum Journal*, *53*(2), 181-189.

Klahr, D. (1999). Exploring science. *The cognition and development of discovery processes.* Massachusetts Institute of technology, USA.

Klahr, D., & Dunbar, K. (1988). Dual space search during scientific reasoning. *Cognitive Science: A Multidisciplinary Journal*, *12* (1), 1 – 48.

Klahr D & Nigam M. (2004). The equivalence of learning paths in early science instruction: Effect of direct instruction and discovery learning. *Psychological Science 15*(10): 661–667.

Klahr, D., Zimmerman, C., & Jirout, J. (2011). Educational interventions to advance children's scientific thinking. *Science*, 333, 971–975.

Kleinbaum, D. G., Kupper, L. L., Muller, K. E., & Nizam, A. (1988). *Applied regression analysis and other multivariable methods* (Vol. 601). Belmont, CA: Duxbury Press.

Klemmer, C. D., Waliczek, T. M., & Zajicek, J. M. (2005). Growing minds: The effect of a school gardening program on the science achievement of elementary students. *HortTechnology*, *15*(3), 448-452.

Koch, S., Waliczek, T. M., & Zajicek, J. M. (2006). The effect of a summer garden program on the nutritional knowledge, attitudes, and behaviors of children. *HortTechnology*, *16*(4), 620-625.

Krajcik, J. S., & Blumenfeld, P. C. (2006). *Project-based learning* (pp. 317-34). na.

Krajcik, J. S., & Mun, K. (2014). Promises and challenges of using learning technologies to promote student learning of science. *Handbook of research on science education*, *2*, 337-360.

Kuhn, D. (1992). Thinking as argument. *Harvard Educational Review*, *62*(2), 155-179.

Kuhn, D. (2000). Metacognitive development. *Current directions in psychological science*, *9*(5), 178-181.

Kuhn, D. (2002). What is scientific thinking and how does it develop. *The Wiley-Blackwell Handbook of Childhood Cognitive Development*, 497- 523.

Kuhn, D. (2008). *Education for Thinking*. Cambridge, Mass: Harvard University Press.

Kuhn, D. (2010). Teaching and learning science as argument. *Science Education*, 94(5), 810–824.

Kuhn, D., Amsel, E., O'Loughlin, M., Schauble, L., Leadbeater, B., & Yotive, W. (1988). *The development of scientific thinking skills*. Academic Press.

Kuhn, D., & Dean, Jr, D. (2004). Metacognition: A bridge between cognitive psychology and educational practice. *Theory into practice*, *43*(4), 268-273.

Kuhn, D., & Franklin, S. (2006). *The second decade: What develops (and how)*. John Wiley & Sons, Inc.

Kuhn, D., Iordanou, K., Pease, M., & Wirkala, C. (2008). Beyond control of variables: What needs to develop to achieve skilled scientific thinking? *Cognitive Development*, *23*(4), 435–451. doi:10.1016/j.cogdev.2008.09.006

Kuhn, D., & Pearsell, S. (2000). Developmental origins of scientific thinking. *Journal of Cognition and Development*, *1*(1), 113-129.

Kuhn, D., Pease, M., & Wirkala, C. (2009). Coordinating the effects of multiple variables: A skill fundamental to scientific thinking. *Journal of Experimental Child Psychology*, *103*(3), 268–284. doi:10.1016/j.jecp.2009.01.009

Kuhn, D., & Udell, W. (2003). The development of argument skills. *Child Development*, *74*(5), 1245-1260.

Larmer, J., Mergendoller, J., & Boss, S. (2015). *Setting the standard for project based learning*. ASCD.

Larochelle, M., & Désautels, J. (1991). 'Of course, it's just obvious': adolescents' ideas of scientific knowledge. *International Journal of Science Education*, *13*(4), 373-389.

Lave, J. (1988). Cognition in Practice: Mind, mathematics, and culture in everyday life. Cambridge, UK: Cambridge University Press.

Lave, J. (1991). Situating learning in communities of practice. *Perspectives on socially shared cognition*, *2*, 63-82.

Lave, J., & Wenger, E. (1991). Situated Learning: Legitimate Peripheral Participation. Cambridge, UK: Cambridge University Press

Leblebicioglu, G., Abik, N. M., Capkinoglu, E., Metin, D., Dogan, E. E., Cetin, P. S., & Schwartz, R. (2017). Science camps for introducing nature of scientific inquiry through student inquiries in nature: Two applications with retention study. *Research in Science Education*, 1-25.

Leblebicioğlu, G., Çapkınoğlu, E., Metin, D., & Schwartz, R. (2017). Views of nature of scientific inquiry of the students in a science high school in Turkey: a vasi application. In *ESERA 2017 Conference, Dubin City University, Irelend.*

Leblebicioglu, G., Metin, D., Capkinoglu, E., Cetin, P. S., Dogan, E. E., & Schwartz, R. (2017). Changes in students' views about nature of scientific inquiry at a science camp. *Science & Education*, *26*(7-9), 889-917.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of research in science teaching*, *29*(4), 331-359.

Lederman, N., & Abd-El-Khalick, F. (1998). Avoiding de-natured science: Activities that promote understandings of the nature of science. In *The nature of science in science education* (pp. 83-126). Springer, Dordrecht.

Lederman, N. G., Antink, A., & Bartos, S. (2014). Nature of science, scientific inquiry, and socio-scientific issues arising from genetics: A pathway to developing a scientifically literate citizenry. *Science & Education*, *23*(2), 285-302.

Lederman, N. G., & Lederman, J. S. (2004). Revising instruction to teach nature of science. *The Science Teacher*, *71*(9), 36.

Lederman N. G., & Lederman, J. S. (2014). Research on teaching and learning of nature of science. In: Lederman, N. G., & Abell, S. K. (2014). *Handbook of research on science education (Vol. II).* Abingdon, England: Routledge

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

Lederman, J., Lederman, N., Bartels, S., Jimenez, J. et al. (2019). An International Collaborative Investigation of beginning Seventh Grade Students' Understandings of Scientific Inquiry: Establishing a Baseline. *Journal of Research in Science Teaching.* Early view, 10.1002/tea.21512

Lederman, J., Lederman, N., Bartels, S., Pavez, J. J., Lavonen, J., Blanquet, E., ... & Gaigher, E. (2017, November). Understandings of scientific inquiry: an international collaborative investigation of seventh grade students. In *ESERA 2017 Conference, Dubin City University, Irelend. https://www. researchgate. net/publication/322603295*.

Lederman, J. S., Lederman, N. G., Bartos, S. A., Bartels, S. L., Meyer, A. A., & Schwartz, R. S. (2014). Meaningful assessment of learners' understandings about scientific inquiry—The views about scientific inquiry (VASI) questionnaire. *Journal of Research in Science Teaching*, *51*(1), 65-83.

Lehrer, R., & Schauble, L. (2006b). *Scientific thinking and science literacy handbook of child psychology*. New York: Wiley.

Lekies, K. S., Yost, G., & Rode, J. (2015). Urban youth′ s experiences of nature: Implications for outdoor adventure recreation. *Journal of Outdoor Recreation and Tourism*, *9*, 1-10.

Liu, C., Liu, E., & Guo, S. (2017). 7th grade VASI study: the case of Beijing. *Enseñanza de las ciencias*, (Extra), 3575-3580.

Linn, M. C., & Eylon, B. S. (2011). *Science learning and instruction: Taking advantage of technology to promote knowledge integration*. Routledge.

Lomas, C., & Oblinger, D. G. (2006). Student practices and their impact on learning spaces. *Learning spaces*, 5-1.

Louv, R. (2008). *Last child in the woods: Saving our children from nature-deficit disorder*. Algonquin books.

Mahr, B. (2011). On the Epistemology of Models. Rethinking Epistemology, 1, 301- 352.

Mara, C. A., & Cribbie, R. A. (2012). Paired-samples tests of equivalence. *Communications in Statistics-Simulation and Computation*, *41*(10), 1928-1943.

McArthur, J., Hill, W., Trammel, G., & Morris, C. (2010). Gardening with youth as a means of developing science, work and life skills. *Children Youth and Environments*, *20*(1), 301-317.

McCrory Wallace, R., Kupperman, J., Krajcik, J., & Soloway, E. (2000). Science on the Web: Students online in a sixth-grade classroom. *The journal of the learning sciences*, *9*(1), 75-104.

McLellan, H. (1993). Evaluation in a situated learning environment. Educational Technology, 33(3), 39-45.

McLellan, H. (1994). Situated learning: Continuing the conversation. Educational Technology, 34(10), 7-8.

Meissner, B. & Bogner, F. X. (2011). Enriching students' education using interactive work-stations at a salt mine turned science center. *Journal of Chemical Education*, 88(4), 510-515

Metin, D., & Leblebicioglu, G. (2015). Development of Elementary 6th and 7th Grade Students' Views about Scientific Model and Modeling throughout a Summer Science Camp. *Egitim ve Bilim*, *40*(177).

Metz, K. E. (2004). Children's understanding of scientific inquiry: Their conceptualization of uncertainty in investigations of their own design. *Cognition and Instruction*, *22*(2), 219-290.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. sage.

Montgomery, T. (2008). Space matters Experiences of managing static formal learning spac-es. *Active Learning in Higher Education*, *9*(2), 122-138.

Moore, J.L., Lin, X., Schwartz, D.L., Petrosino, A., Hickey, D.T., Campbell, O., Hmelo, C., & Cognition and Technology Group at Vanderbilt. (1994). The relationship between situated cognition and anchored instruction: A response to Tripp. Educational Technology, 34(10), 28-32.

Morentin, M., & Guisasola, J. (2015). The role of Science Museum field trips in the Primary Teacher preparation. *International Journal of Science and Mathematics Education*, *13*(5), 965-990.

Morgan, P. J., Warren, J. M., Lubans, D. R., Saunders, K. L., Quick, G. I., & Collins, C. E. (2010). The impact of nutrition education with and without a school garden on knowledge, vegetable intake and preferences and quality of school life among primary-school students. *Public health nutrition*, *13*(11), 1931-1940.

Morris, B. J., Masnick, A. M., Zimmerman, C., & Croker, S. (2012). *The emergence of scientific reasoning*. INTECH Open Access Publisher.

Mills, K. L., Lalonde, F., Clasen, L. S., Giedd, J. N., & Blakemore, S. J. (2014). Developmental changes in the structure of the social brain in late childhood and adolescence. *Social Cognitive and Affective Neuroscience*, *9*(1), 123-131.

National Governors Association Center for Best Practices, Council of Chief State School Officers Title: Common Core State. Publisher: National Governors Association Center for Best Practices, Council of Chief State School Officers, Washington D.C. Copyright Date: 2010

National Research Council. (2000). Inquiry and the National Science Education Standards. A Guide for Teaching and Learning Washington, DC: National Academy Press.

National Research Council (2007). *Taking science to school: learning and teaching science in* *grades K-8*. Washington, D.C: National Academies Press.

National Research Council. (2008). Research on future skill demands. Washington, DC: National Academies Press.

National Research Council (U.S.), & Bell, P. (Eds.). (2009). Learning science in informal environments: people, places, and pursuits. Washington, D.C: National Academies Press.

National Research Council (2012a). Education for life and work: developing transferable knowledge and skills in the 21st century. Committee on Defining Deeper Learning and 21st Century Skills. In: Pellegrino, J. W., & Hilton, M. (Eds.). Washington, DC: Board on Testing and Assessment and Board on Science Education,1; Division of Behavioral and Social Sciences and Education.

National Research Council (2012b). A framework for K-12 science Education: practices, crosscutting concepts, and core ideas. Washington, DC: Committee on a Conceptual Framework for New K-12 Science Education Standards, Board on Science Education, Division of Behavioral and Social Sciences and Education.

National School Lunch Program. Retrieved from https://www.benefits.gov/benefits/benefit-details/1960

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

Nisbet, M., & Dudo, A. (2011). Science, entertainment, and education: a review of the literature," Report for the National Academy of Sciences.

Oblinger, D. (2006). *Learning spaces* (Vol. 2). Washington, DC: Educause.

O'Brien, S. A., & Shoemaker, C. A. (2006). An after-school gardening club to promote fruit and vegetable consumption among fourth grade students: The assessment of social cognitive theory constructs. *HortTechnology*, *16*(1), 24-29.

Orr, D. W. (1992). *Ecological literacy: Education and the transition to a postmodern world*. Suny Press.

Osborne, J. (2013). The 21st century challenge for science education: Assessing scientific reasoning. *Thinking Skills and Creativity*, *10*, 265–279. doi:10.1016/j.tsc.2013.07.006

Osborne, J., (2014). Teaching Scientific Practices: Meeting the Challenge of Change, Journal of Science Teacher Education, 25:2, 177-196

Osborne, J. (2014). Scientific practices and inquiry in the science classroom. In: Lederman, N. G., & Abell, S. K. (2014). *Handbook of research on science education (Vol. II).* Abingdon, England: Routledge.

Osborne, J., Collins, S., Ratcliffe, M., Millar, R., & Duschl, R. (2003). What ideas about science should be taught in school science? A Delphi study of the expert community. *Journal of Research in Science Teaching*, *40*(7), 692–720. doi:10.1002/tea.10105

Ozer, E. J. (2007). The effects of school gardens on students and schools: Conceptualization and considerations for maximizing healthy development. *Health Education & Behavior*, *34*(6), 846-863.

Palincsar, A.S. (1989). Less charted waters. *Educational Researcher*, 18(5), 5-7.

Passy, R. (2014). School gardens: Teaching and learning outside the front door. *Education 3-13*, *42*(1), 23-38.

Pigg, A. E., Waliczek, T. M., & Zajicek, J. M. (2006). Effects of a gardening program on the academic progress of third, fourth, and fifth grade math and science students. *HortTechnology*, *16*(2), 262-264.

Pudup, M. B. (2008). It takes a garden: Cultivating citizen-subjects in organized garden projects. *Geoforum*, *39*(3), 1228-1240.

Quay, J. (2003). Experience and participation: Relating theories of learning. *Journal of Experiential Education*, *26*(2), 105-112.

Rasch, D., Teuscher, F., & Guiard, V. (2007). How robust are tests for two independent samples?. *Journal of Statistical Planning and Inference*, *137*(8), 2706-2720.

Ratcliffe, M. M., Merrigan, K. A., Rogers, B. L., & Goldberg, J. P. (2011). The effects of school garden experiences on middle school-aged students' knowledge, attitudes, and behaviors associated with vegetable consumption. *Health promotion practice*, *12*(1), 36-43.

Rennie, L. J. (2007). Learning Science Outside of School. In: Lederman, N. G., & Abell, S. K. (2007). *Handbook of research on science education, 1*,125-170. Mahwah, NJ: Lawrence Erlbaum Associates.

Rennie, L. J. (2014). Learning science outside of school. In: Lederman, N. G., & Abell, S. K. (2014). *Handbook of research on science education (Vol. II).* Abingdon, England: Routledge.

Resnick, L. (1987). Learning in school and out. *Educational Researcher*, 16(9), 13-20.

Reyna, V. F., Chapman, S. B., Dougherty, M. R., & Confrey, J. E. (2012). *The Adolescent Brain: Learning, Reasoning, and Decision Making*. American Psychological Association.

Roberts, D. A. (2007). Scientific literacy/science literacy. In: Lederman, N. G., & Abell, S. K. (2007). *Handbook of research on science education*, *1*, 120-144. Mahwah, NJ: Lawrence Erlbaum Associates.

Roberts, D. A., & Bybee, R. W. (2014). Scientific literacy, science literacy, and science education. In: Lederman, N. G., & Abell, S. K. (2014). *Handbook of research on science education (Vol. II).* Abingdon, England: Routledge.

Robinson, C. W., & Zajicek, J. M. (2005). Growing minds: The effects of a one-year school garden program on six constructs of life skills of elementary school children. *HortTechnology*, *15*(3), 453- 457.

Rochon, J., Gondan, M., & Kieser, M. (2012). To test or not to test: Preliminary assessment of normality when comparing two independent samples. *BMC medical research methodology*, *12*(1), 81.

Ross, A., & Willson, V. L. (2018). *Basic and advanced statistical tests: Writing results sections and creating tables and figures*. Springer.

Roth, W.-M. (2012). Science of learning is learning of science: why we need a dialectical approach to science education research. *Cultural Studies of Science Education*, *7*(2), 255–277. doi:10.1007/s11422-012-9390-6

Sacco, K., Falk, J. H., & Bell, J. (2014). Informal Science Education: Lifelong, Life-Wide, Life-Deep. *PLoS Biology*, *12*(11), e1001986. doi:10.1371/journal.pbio.1001986

Sadler, T. D., Chambers, F. W., & Zeidler, D. L. (2004). Student conceptualizations of the nature of science in response to a socioscientific issue. *International Journal of Science Educa-*

tion, *26*(4), 387-409.

Sandoval, W. A., & Harven, A. M. (2011). Urban Middle School Students' Perceptions of the Value and Difficulty of Inquiry. *Journal of Science Education and Technology*, *20*(1), 95–109. doi:10.1007/s10956-010-9237-4

Sandoval, W. A., Sodian, B., Koerber, S., & Wong, J. (2014). Developing Children's Early Competencies to Engage With Science. *Educational Psychologist*, *49*(2), 139–152. doi:10.1080/00461520.2014.917589

Sasson, I., & Cohen, D. (2013). Assessment for effective intervention: enrichment science academic program. *Journal of Science Education and Technology*, *22*(5), 718-728.

Sawyer, R. K. (Ed.). (2005). *The Cambridge handbook of the learning sciences*. Cambridge University Press.

Schauble, L. (1996). The development of scientific reasoning in knowledge-rich contexts. *Developmental Psychology*, *32*(1), 102–119. doi:10.1037/0012-1649.32.1.102

Schreiber, J. B. (2013). Informal Environments. *The Journal of Educational Research*, *106*(6), 421–422. doi:10.1080/00220671.2013.836874

Schwan, S., Grajal, A., & Lewalter, D. (2014). Understanding and engagement in places of science experience: Science museums, science centers, zoos, and aquariums. *Educational Psychologist*, *49*(2), 70-85.

Schwarz, C. V., & White, B. Y. (2005). Metamodeling knowledge: Developing students' understanding of scientific modeling. *Cognition and instruction*, *23*(2), 165-205.

Science education based around modeling would development students understanding about this aspect as well as helping students comprehend the topic at more depth.

Schwartz, R. (n.d.). Nature of Science and Model Competence. In *Towards a Competence-based View on Models and Modeling in Science Education*. Dordrecht: Springer.

Schwartz, R. & Crawford, B. (2004). Authentic scientific inquiry as context. In: Flick, L. B., & Lederman, N. G., (eds) *Scientific Inquiry and Nature of Science. Implications for teaching, learning, and teacher education*, 1(25). Springer, Dordrecht

Schwartz, R. S., Lederman, N. G., & Crawford, B. A. (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.

Schwartz, R. S., Lederman, N. G., & Lederman, J. S. (2008). Proceedings from NARST 2008: An Instrument To Assess Views Of Scientific Inquiry: The VOSI Questionnaire. Baltimore, MD.

Schwartz, R., & Lederman, N. (2008). What scientists say: Scientists' views of nature of science and relation to science context. *International Journal of Science Education*, *30*(6), 727-771.

Schwartz, R. S., & Lederman, N. G. (2002). "It's the nature of the beast": The influence of knowledge and intentions on learning and teaching nature of science. *Journal of Research in science teaching*, *39*(3), 205-236.

Schwartz, R. S., & Lederman, N. G. (2005). Proceedings from AERA 2005: What Scientists Say: Scientists' Views of Models. Montreal. Canada.

Shouse, A., Lewenstein, B., Feder, M., & Bell, P. (2010). Crafting Museum Experiences in Light of Research on Learning: Implications of the National Research Council's Report on Informal Science Education. *Curator: The Museum Journal*, *53*(2), 137-154.

Siegler, R. S. (1996). *Emerging minds: The Process of Change in Children's Thinking*. New York, NY: Oxford University Press.

Siegler, R. S. (1999). Strategic development. *Trends in Cognitive Sciences,3*(11), 430-435.

Skelly, S. M., & Zajicek, J. M. (1998). The effect of an interdisciplinary garden program on the environmental attitudes of elementary school students. *HortTechnology*, *8*(4), 579-583.

Smith, C. L., Maclin, D., Houghton, C., & Hennessey, M. G. (2000). Sixth-grade students' epistemologies of science: The impact of school science experiences on epistemological development. *Cognition and Instruction*, *18*(3), 349-422.

Songer, N. B. (2007). Digital resources versus cognitive tools: A discussion of learning. *Handbook of research on science education*, *471*.

Spiegel, A. N., Evans, E. M., Frazier, B., Hazel, A., Tare, M., Gram, W., & Diamond, J. (2011). Changing museum visitors' conceptions of evolution. *Evolution: Education and Outreach*.

Spires, H. A., Hervey, L. G., Morris, G., & Stelpflug, C. (2012). Energizing Project-Based Inquiry: Middle-Grade Students Read, Write, and Create Videos. *Journal of Adolescent & Adult Literacy*, *55*(6), 483-493.

Stavrova, O. & Urhahne, D. (2010). Modification of a school programme in the Deutsches Museum to enhance students' attitudes and understanding. *International Journal of Science Education*, 32(17), 2291-2310.

Steinberg, L., Vandell, D., & Bornstein, M. (2011). *Development: Infancy through Adolescence.* Belmont, CA: Wadsworth.

Sturm, H. & Bogner, F.X. (2010). Learning at workstations in two different environments: A museum and a classroom. *Studies in Educational Evaluation*, *36*(1/2), 14-19.

Szu, E., Osborne, J., & Patterson, A. D. (2017). Factual accuracy and the cultural context of science in popular media: Perspectives of media makers, middle school students, and university students on an entertainment television program. *Public Understanding of Science*, *26*(5), 596-611.

Tabachnick, B. G., Fidell, L. S., & Ullman, J. B. (2007). *Using multivariate statistics* (Vol. 5). Boston, MA: Pearson.

Tal, T., & Dierking, L. D. (2014). Learning Science in Everyday Life. *Journal of Research in Science Teaching*, *51*(3), 251–259. doi:10.1002/tea.21142

Tobias, S., & Duffy, T., M., (Eds). (2009) *Constructivist Theory Applied to Instruction: Success or Failure?* Taylor and Francis, London.

Trelstad, B. (1997). Little Machines in Their Gardens: A History of School Gardens in America, 1891 to 1920. *Landscape Journal*,*16*(2), 161-173. Retrieved from http://www.jstor.org/stable/43323438

Turner, L., Eliason, M., Sandoval, A., & Chaloupka, F. J. (2016). Increasing prevalence of US elementary school gardens, but disparities reduce opportunities for disadvantaged students. *Journal of School Health*, *86*(12), 906-912.

Urban Areas. Retrieved from https://www.census.gov/geo/reference/urban-rural.html

U.S. Department of Education (2010). Title 1. Retrieved from https://www2.ed.gov/programs/titleiparta/index.html

Vygotsky, L. (1978). Interaction between learning and development. *Readings on the development of children*, *23*(3), 34-41.

Vygotsky, L. S. (1980). *Mind in society: The development of higher psychological processes*. Harvard university press.

Vygotsky, L. S. (1997). *The collected works of LS Vygotsky: Problems of the theory and history of psychology* (Vol. 3). Springer Science & Business Media.

Waite, S. (2010). Losing our way? The downward path for outdoor learning for children aged 2–11 years. *Journal of Adventure Education & Outdoor Learning*, *10*(2), 111-126.

Waliczek, T. M., & Zajicek, J. M. (1999). School gardening: Improving environmental attitudes of children through hands-on learning. *Journal of environmental horticulture*, *17*(4), 180-184.

White, B., Frederiksen, J., & Collins, A. (2009). The interplay of scientific inquiry and metacognition: More than a marriage of convenience. *Handbook of metacognition in education*, 175-205.

Whitebread, D. (2011). Metacognition, strategy use & instruction. *Educational Review*, *63*(3), 380-382.

Whitesell, E. R. (2016). A day at the museum: The impact of field trips on middle school science achievement. *Journal of Research in Science Teaching*.

Whiteside, A., & Fitzgerald, S. (2009). Designing learning spaces for active learning. *Implications*, *7*, 1-6.

Williams, D., & Brown, J. (2013). *Learning gardens and sustainability education: Bringing life to schools and schools to life*. Routledge: Taylor and Francis.

Williams, D. R., & Dixon, P. S. (2013). Impact of garden-based learning on academic outcomes in schools: Synthesis of research between 1990 and 2010. *Review of Educational Research*, *83*(2), 211-235.

Williamson, R., & Smoak, E. (1999). Creating a Down-to-Earth Approach to Teaching Science, Math and Technology. *Journal of Extension*, *37*(3).

Wilson, B. G., & Myers, K. M. (2000). Situated cognition in theoretical and practical context. *Theoretical foundations of learning environments*, 57-88.

Winn, W. (1993). Instructional design and situated learning: Paradox or partnership. Educational Technology, 33(3), 16-21.

Yang, I. H., Park, S. W., Shin, J. Y., & Lim, S. M. (2017). Exploring Korean Middle School Students' View about Scientific Inquiry. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(7), 3935-3958.

Yoon, S. A., Elinich, K., Wang, J., Steinmeier, C., & Tucker, S. (2012). Using augmented reality and knowledge-building scaffolds to improve learning in a science museum. *International Journal of Computer-Supported Collaborative Learning*, *7*(4), 519-541.

Young, M.F. (1993). Instructional design for situated learning. Educational Technology Research and Development, 41(1), 43-58.

Young, M.F. (1995). Assessment of situated learning using computer environments. Journal of Science Education and Technology, 4(1), 89-96.

Zeidler, D. L., Walker, K. A., Ackett, W. A., & Simmons, M. L. (2002). Tangled up in views: Beliefs in the nature of science and responses to socioscientific dilemmas. *Science education*, *86*(3), 343-367.

Zimmerman, C. (2000). The Development of Scientific Reasoning Skills. *Developmental Review*, *20*(1), 99–149. doi:10.1006/drev.1999.0497

Zimmerman, C. (2007). The development of scientific thinking skills in elementary and middle school. *Developmental Review*, *27*(2), 172–223. doi:10.1016/j.dr.2006.12.001

Zohar, A., & Peled, B. (2008). The effects of explicit teaching of metastrategic knowledge on low- and high-achieving students. *Learning and Instruction*, *18*(4), 337–353. doi:10.1016/j.learninstruc.2007.07.001

APPENDICES

Appendix A: Inquiry School Garden Lessons

Name of Lesson: Lesson 1 How do we investigate world hunger?			**Prepared by:** Carmen Carrion
Resource:			**Date: February 2018**
Topic: Investigating	**Grade Level: 6th**	**Total time estimate: 55min**	

Connections to NGSS:

NGSS- MS- ETS1-1 Defining the criteria and constraints of a design problem while taking into account a successful solution. Students must also take into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

NGSS- MS- ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

NOSI Aspect:

Asking questions

There is no single set or sequence of steps followed in all investigations.

Inquiry procedures are guided by the question asked.

Overview/ Purpose/Assumptions:

During this lesson students will learn what is world hunger. They will then take this knowledge to design a school garden. Students will have the learning opportunity to work with one another to create a solution for world hunger.

Content Learning Outcomes: Students will be able to explain what is world hunger. Students will also learn how to design a garden after researching and investigating how to design one.

NOSI Learning Outcomes: This lesson will clearly demonstrate inquiry and allow the students to demonstrate how the sciences are subjective and tentative by nature and the use of creativity within the investigation process.

Science Practices Outcomes:

- Asking questions and defining problems in 6–8 builds on K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.

-Planning and carrying out investigations in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions.

- Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.

Connections to Inquiry: (explain where and how in the lesson your NOS, NOSI, and science practices expected outcomes are explicitly addressed.)

During the investigation I will introduce how questions guide our investigation.

During the discussion post investigation, I point out how groups have different designs/solutions for solving world hunger, detailing how subjectivity and creativity played a role during the investigation.

Materials required:

- Field notebooks
- ipads

Section of Lesson	**Time estimate**	**Teacher Guide** (what is the teacher doing)	**Planned questions, activities, & assessments**	**Student guide** (what are the students doing)
Opening	10 mins	*Ice Breaker*	**I show pictures world hunger. Then show pictures of different natural disasters affecting fields. I will also show how organisms such as different insects can destroy crops. Ask students " How might these pictures be connected?"**	Students participate in ice breaker activity by telling me what they see. Discuss world hunger and how scientists and engineers are trying to combat these factors on different levels.

	15mins	*Leading the students in discussion, writing their thoughts on the board.* ***-Allow students to make guesses of what they think and have them write them on the right side of the board.*** *Student chosen at Teachers discretion. We will chose through hand raising and random selection. Involve everyone.*	What do you think are nonliving factors? What do you think are living factors? What do these factors end up contributing too? World hunger! Student will investigate hunger statistics: How much hunger is found across the world? How much hunger is found in the US? How much hunger is found in the Atlanta metropolitan area? How many children in the Atlanta metropolitan area go hungry everyday?	Students are participating in discussion, sharing their ideas. Students in groups will use the ipads to research the hunger statistics.

Body	20 mins	Discuss investigations. -What is an investigation and why is it useful? -Ask for and/or Give examples of investigations Discuss the importance of questioning in science. Assigning groups 3 – 4 per group.	For your class today you and your group will design an investigation to help solve world hunger. All investigations are driven by questioning. “How do you believe an investigation begins? What do you need?” What affects world hunger? How do we know? **NOSI**: Pose the question can we all have the same guiding question but come up with a difference investigation from one another? What is our guiding question?	Discuss what investigations do. Why they are important. Discuss ways the school can help solve world hunger. Students are grouped into 3’s or 4’s. Students sharing ideas. And giving examples of ways to solve world hunger.

		Begin explaining that they students will have a typical garden outside and a garden made out of recyclable materials outside as well. Explain to student how investigations can be simple. But that a simple investigation can give a lot of information. Give student examples.	"How do these questions guide your investigation? [**NOSI**] Point out "Will all groups have the same conclusions at the end of an investigation? Will all groups have the same guiding question? What if groups have the same guiding question? Explain to students how scientists and engineers can have the same guiding question but use different approaches to achieve their goals. Explain each group has a garden bed but all groups may grow and investigate different plants.	Students are discussing why a simple investigation could be useful.
Closing	10 mins	*Lead students in discussion* I will ask what are we investigating? What is our guiding question?	Have students from each group present their investigation design. What were the differences between some of the groups' investigations for a garden?	During discussion, students should present the investigation they designed and explain what their driving question is.

		Will discuss with students how different groups have the same guiding questions. And how some groups may the same question but may investigate something differently. *[need expected answers]*	Were any the same? Go over the original the subjective and tentative nature of science. Each group can design a different investigation around the same question. **[NOSI]** **NOSI**-Discuss subjectivity and creativity, each group of students may have different investigations, and conclusions for what they think is needed for the gardens. What type of information did you use to design your investigation? [what students knew about the process]. Why didn't everyone do it the same way? [different experiences and expectations] How do scientists' experiences and expectations influence how they do science? [make decisions based on what they know and think is important....This is subjectivity [NOSI].	
Extension activities (plans for early finishers)		*May begin to look up plants to plant in Ga in the spring.*	Have students who finish early research, what kind of plants grow in Ga in the fall.	Students work individually on the ipads, while other students finish.
Assessment plans Exit Slip: Fill out 3 questions about group dynamics.				

Name of Lesson: Lesson 2 Surveying the land and soil composition Part 1			**Prepared by:** Carmen Carrion
Resource:			**Date: February 2018**
Topic: Engineering	**Grade Level: 6th**	**Total time estimate: 100min**	

Connections to NGSS:

NGSS- MS- ETS1-1 Defining the criteria and constraints of a design problem while taking into account a successful solution. Students must also take into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

NGSS- MS- ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

NOSI Aspect:

Asking questions
Multiple methods for the same question
Different conclusions may be justifiable from the same set of data or information
Data and evidence: sources, roles of, and distinctions between

Overview/ Purpose/Assumptions:

Students will learn how to survey land.
Students will practice observation skills.
Students will calculate the perimeter, surface area, and volume of their plots.

Content Learning Outcomes:

Students will be able to explain what factors need to be accounted for when designing a garden. Students will also discover the differences between parameter, surface area, and volume.

NOSI Learning Outcomes:

This lesson will clearly demonstrate inquiry and allow the students to understand how their guiding question relates to the design of their gardens. Furthermore, not all students will use the same procedure but may have the same conclusions.

Science Practices Outcomes:

- Asking questions and defining problems in 6–8 builds on K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.

- Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.

- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.

-Mathematical thinking in 6–8 builds on K–5 experiences and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.

Connections to Inquiry: (explain where and how in the lesson your NOS, NOSI, and science practices expected outcomes are explicitly addressed.)

During the investigation design I will introduce how questions guide our investigation.

I will also discuss how several solutions can arise from the same guiding question.

During the discussion, post surveying investigation, I will point out how groups have different observations about the garden plots and how subjectivity played a role during the investigation.

Materials required:

- Field notebooks
- Writing utensil
- Calculator
- Tape measure

Section of Lesson	**Time estimate**	**Teacher Guide** (what is the teacher doing)	**Planned questions, activities, & assessments**	**Student guide** (what are the students doing)
Opening	15 mins	*Ice Breaker*	Pictures of large farms and engineering feats. Ask students, “Do these large engineering feats happen miraculously? What do farmers and engineers do before plant-	Students participate in ice breaker activity by telling me what they see. They answer “Surveying the land!”

		Leading the students in discussion, writing their thoughts on the board. ***-Allow students to make guesses of what they think and have them write them on the right side of the board.*** *Student chosen at Teachers discretion. We will chose through hand raising and random selection. Involve everyone.*	ing or building?" ***Ask class what is surveying and why is it important.*** You are all farmers. Your school garden plot is your farm. Do you think you can start planting anywhere? NO! There are several factors that come into play such as: rain, erosion, wind, etc all of these elements can effect if your farm will be successful.	Students are participating in discussion, sharing their ideas
Body	15 mins	Begin explaining that the students must figure out what factors affect the placement of a garden plot.	For your class today you and your group will survey the land of your future garden plot. **NOSI**: Pose the question what is our guiding question?	Discuss what to do when surveying the land.

			How does the guiding question affect surveying the garden plot? What are features we should look for in our plot? Is your plot on a hill or in a ditch or on a flat surface? Predict the best surface and decide why.	Students are in groups. Students sharing ideas. And giving examples things to look for.
		Discuss why these factors all are important when surveying the land.	Will your plot receive plenty of sunlight? Is your plot in an open space or surrounded by trees? Will shade affect your plot? Argue how shade can affect your plot. How much rain does this area receive? Determine how much rain your plot may receive. Is the area windy? Determine how much wind your plot may receive.	Students write answers in their field notebooks.
	30min	Take students outside	While outside all students are writing down observations of the potential garden plot areas. Students may also take pictures.	Students are writing observations of their garden plot or using ipads for taking pictures.

			"Do all students have the same observations? What might matter to one group may not affect another group" [**NOSI**]	
		Ask students about the type of math used when engineering a garden plot.	What math do farmers need to know? Give examples and explain. Perimeter Surface area Volume	
			How can we take these measurements? What do we need? Height Length Width	Students use tape measures to measure garden plots.
	20min	Class returns inside	How do we calculate perimeter? Give formula How do we calculate surface area? Give Formula	Students break into groups to make calculations for the garden plot.

			How do we calculate volume? Give formula What do each of these measurements tell us? How does this relate to the garden plot? As students come up with answers explain that the answer can be calculated more than one way. [NOSI] Not just one set way to come up with conclusions.	
Closing	20min mins	*Lead students in discussion* I will choose some one from each group to explain what is our guiding question and how does surveying the land relate to the guiding question. Will discuss with students how different groups had different answers even though the guiding question is the	Have students explain factors for farming/engineering. The importance of planning and organizing before an investigation. What were the differences between some of the groups' surveying? Were any the same? Go over the original the subjective and tentative nature of science. Each group can survey the land with the same guiding question but still be interested in different factors. **[NOSI]**	During discussion, students should discuss the factors their groups chose and explain why those factors are important for their garden plot.

		same.	What type of information did you use to survey the land? [what students knew about the process]. Why didn't everyone do it the same way? [different experiences and expectations] How do scientists', engineers, and farmers experiences and expectations influence how they come up with a solution? [make decisions based on what they know and think is important....This is subjectivity [NOSI]. Did all of you survey the same way? There is no single set or sequence of steps followed in all investigations [NOSI].	
Extension activities (plans for early finishers)		*May begin to look up plants to plant in Ga in the fall.*	Have students who finish early research, what kind of plants grow in Ga in the fall.	Students work individually on the ipads, while other students finish.
Assessment plans Exit Slip: 3 group dynamic questions.				

Name of Lesson: Lesson 2 Surveying the land and soil composition Part 2			**Prepared by:** Carmen Carrion
Resource:			**Date: February 2018**
Topic: Soil composition	**Grade Level: 6th**	**Total time estimate: 100min**	
Connections to NGSS: MS- ETS1-1 Defining the criteria and constraints of a design problem while taking into account a successful solution. Students must			

also take into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS- ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3 Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Connections to Georgia Standards of Excellence:

S6E5. Obtain, evaluate, and communicate information to show how Earth's surface is formed.

a. Ask questions to compare and contrast the Earth's crust, mantle, inner and outer core, including temperature, density, thickness, and composition.

b. Plan and carry out an investigation of the characteristics of minerals and how minerals contribute to rock composition.

c. Construct an explanation of how to classify rocks by their formation and how rocks change through geologic processes in the rock cycle.

d. Ask questions to identify types of weathering, agents of erosion and transportation, and environments of deposition. (Clarification statement: Environments of deposition include deltas, barrier islands, beaches, marshes, and rivers.)

NOSI Aspect:

All scientists performing the same procedure may not get the same results.
Multiple methods for the same question.
Different conclusions may be justifiable from the same set of data or information.
Scientific data are not the same as scientific evidence.

Overview/ Purpose/Assumptions:

Students will be able to identify sand, silt, and clay in a soil sample.
Students will be able to explain physical properties of the three soil components.
Students will be able to describe the makeup of healthy garden soil.

Explain why two individuals may have the same procedures but have different conclusions.

Content Learning Outcomes:
Students will be able to explain and identify different components of soil.

NOSI Learning Outcomes:

This lesson will clearly demonstrate inquiry by allowing students to gather their own soil samples and identifying what is in their samples. They will also experience the subjectiveness of science by comparing their group's samples to other groups' samples. Lastly students will see how different conclusions ca be made even though students are going through the same procedures.

Science Practices Outcomes:

- Asking questions and defining problems in 6–8 builds on K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.

-Planning and carrying out investigations in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions.

Connections to Inquiry: (explain where and how in the lesson your NOS, NOSI, and science practices expected outcomes are explicitly addressed.)

During the soil investigation I will introduce how questions guide our investigation.

During the soil sample gathering I will point out how different groups have types of samples even though we all have the same guiding question.

During the discussion post soil investigation, I point out how groups have different conclusions detailing how subjectivity played a role during the investigation.

Materials required:

- Field notebooks
- Gloves
- Plastic cups
- Hand shovels
- Different soil samples: sand, silt, and clay

Section of	**Time es-**	**Teacher Guide** (what	**Planned questions, activities, & assess-**	**Student guide** (what are the students

Lesson	timate	is the teacher doing)	ments	doing)
Lesson	**timate**	is the teacher doing)	**ments**	doing)
Opening	10 mins 15mins	*Ice Breaker* *Discussion about soil composition. Give students three buckets without labels.* -***Allow students to make guesses of what they think and have them write them on the board***. *Discuss the different physical properties of*	**I show a picture of a garden. Give students the task of grouping the plants in the garden.** **Ask different students how they came up with their conclusion.** **Discuss how the students had the same procedure but they all have different conclusions or ways of grouping the plants in the garden.** **I show pictures of different types of soil. "Is all soil the same?" What makes soils different?** Does soil affect plant growth? Explain What soil is made up of? Sand, silt, and clay. Have students look and touch inside of each bucket. Students try to figure out which bucket is	Students participate in ice breaker activity by telling me what they see. Discuss how soil affects plant grow Students touch, smell, and look at the different soil samples. Students are figuring out what different properties make up soil.

		soil. Discuss how each type is different (lots of air and water can get in between large sand particles, not as much air and water can get through silt particles, almost no air can water get through clay particles).	silt, sand, and clay. Explain that there are three types of soil: sand (largest particles), silt (medium particles), and clay (smallest particles). How might these three types of particles settle in a jar when a soil sample is taken, why?	
Body	40 mins	The entire class will now go outside. Have each group go outside to collect soil samples of their own. Label the different soil samples by location. For example: by the football field, under pine trees, etc.	For your class today you and your group will go outside to collect different soil samples. Each group must collect at least 3 samples. **NOSI**: Pose the question will all groups have the same soil samples? Why or why not. Come back inside with groups. Have	Go outside. Collect samples from various areas. Label each sample.

	20mins	Come back instead. Have students examine their soil samples. Write descriptions about each sample. Each group is creating a conclusions and explanations for their soil samples.	groups begin looking over their samples. Point out "Will all groups have the same samples? Did all groups have the same guiding question? Is it ok that we have different samples? **[NOSI]** Explain to students how scientists and engineers can have the same guiding question but use different approaches to achieve their goals. Now look at your soil using the data you have collected what conclusions can you make about your samples? **[NOSI]**	Being examining soil samples. Will write descriptions about each sample. Students are looking over their samples and writing conclusions and explanations.
Closing	15 mins	*Lead students in discussion* I will choose one student from each group to present one of their soil samples. Will discuss with students how different groups had different soil	**NOSI**-Discuss subjectivity, each group of students may have different soil samples, and conclusions for what kind of soil they found. **NOSI** - Discuss why some groups have different conclusions but have similar data sources. Why is it important to know what kind of	During discussion, students should present their samples and conclusions.

		samples even though the class had the same guiding question.	soil you are gardening in? What type of soil is best for gardening? Why? How can you change the composition of the soil? What are somethings you can add to the soil to make it better for gardening?	
Extension activities (plans for early finishers)		*May begin to look up plants to plant in Ga in the fall.*	Have students who finish early research, what kind of plants grow in Ga in the fall.	Students work individually on the ipads, while other students finish.
Assessment plans Exit Slip: Answer 3 questions about group dynamics.				

Name of Lesson: Lesson 3 topic: How do we plant? Part 1			**Prepared by:** Carmen Carrion
Resource:			**Date: February 2018**
Topic: Planting	**Grade Level: 6th**	**Total time estimate: 55**	
Connections to NGSS:			
MS-LS1-5.	Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms. Clarification Statement: Examples of local environmental conditions could include availability of food, light, space, and water		

Overview/ Purpose/Assumptions:

During this lesson students will investigate how food, light, space, and water all affect plant growth.

Content Learning Outcomes:

Students will be able to identify what factors affect plant growth.

NOSI Learning Outcomes:

Students will also learn that the procedures may be given but not all group's plant beds will look the same.

Explanations are developed from a combination of collected data and what is already known. Students learn to collect data over time but will use currently known evidence to guide their planting.

Science Practices Outcomes:

Constructing explanations and designing solutions in 6–8 builds on K– 5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.

Connections to Inquiry and NOS: (explain where and how in the lesson your NOS, NOSI, and science practices expected outcomes are explicitly addressed.)

During the planting activity I will introduce data, evidence, observation, and inference.

Materials required:

- plants
- field notebooks
- soil
- gardening gloves
- pots
- tags for plants
- mini shovel
- ipads

Safety Concerns:

- Be respectful of classroom and classmates
- Inside voices
- Walking feet at all times
- No horseplay
- Goggles to be worn at all times during investigation
- No eating, drinking or consuming any materials in lab, unless instructed otherwise.
- Clean up; all materials should be back in Ms. Sureka's room.
- HAVE FUN!

Section of Lesson	**Time estimate**	**Teacher Guide** (what is the teacher doing)	**Planned questions, activities, & assessments**	**Student guide** (what are the students doing)
Opening	20 mins	*Ice Breaker* Discuss observation and inference here. [**NOSI**} Observation is what is observed or measured or sensed with the senses. Inference is an offered explanation for the observation. EX: You observe someone come into class with soaking	**Show class a picture of a boy in a lake with a goat and a broken branch also in the picture.** **Show class a picture that can be seen in two different ways.** **What do you observe? What do you infer?** **NOSI**: Pose the question of what is an observation? What is an inference? Can you give me an example of each? Should be written in field notebooks.	Students participate in ice breaker activity. Learn difference between inference and observation. Students are participating in discussion, sharing their ideas

		wet clothes. You may infer that it is raining outside. Pose the question of what is an observation? What is an inference? Can you give me an example of each? This should be written in the field notebooks.		
Body	20min	Revisit what factors affect plant growth. Remind students the plants they are planting today are for learning how to collect qualitative and quantitative data. I will be moving through the class ob-	What affects plant growth? What kind of factors are these: living or nonliving? Do all of these planting need to have the same water, soil, and sunlight amount? Explain to me why. How does this relate to control of variables? "How do we know the plants need a certain amount of sunlight and water? What EVIDENCE do we have?	Students will work in groups. Students sharing ideas. And giving examples of observations and inferences.

		serving the students and asking questions as they plant.	Remind the class what evidence is as I walk around the classroom. [**NOSI**]	
	Clean up	Help students put items away		Will return things to Ms. Sureka's classroom.
Closing	15 mins	*Lead students in discussion* *What is an observation? What is an inference?*	"What evidence do we have about what resources these plants need?" "What is evidence?" "Why is evidence important?" **[NOSI]** What type of information did you use to make your decisions? [what students knew about the process]. Why didn't everyone do it the same way? [different experiences and expectations] How do scientists experiences and expecta-	Class discussion

			tions influence how they do science? [make decisions based on what they know and think is important....This is subjectivity]	
Extension activities (plans for early finishers)		*Walking around the classroom, helping with planting*	Have students who finish early help with clean up.	Students help with clean up.
Assessment plans Exit Slip: Students answer 3 group dynamic questions.				

Name of Lesson: Lesson 3 topic: How do we plant? Part 2			**Prepared by:** Carmen Carrion
Resource:		**Do everyday for data collection**	**Date: February 2018**
Topic: Planting	**Grade Level: 6th**	**Total time estimate: 55**	
Connections to NGSS: **MS-LS1-5.** **Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.** Clarification Statement: Examples of local environmental conditions could include availability of food, light, space, and water			
Overview/ Purpose/Assumptions: During part 2 of this lesson students will investigate how food, light, space, and water all affect plant growth by collecting qualitative and quantitative data about their plants and then analyzing and the interpreting the data into evidence. They will use their evidence to make claims about how their plants grew.			

Content Learning Outcomes:
Students will be able to identify what factors affect plant growth by analyzing the data they collect at the end of the 40 days of plant growth.

NOSI Learning Outcomes:

Scientific investigations all begin with a question and do not necessarily test a hypothesis.

Scientific data are not the same as scientific evidence.

All scientists performing the same procedure may not get the same results.

Research conclusions must be consistent with the data collected.

Explanations are developed from a combination of collected data and what is already known.

Science Practices Outcomes:

Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.

Obtaining, evaluating, and communicating information and using this information to create explanations.

Connections to Inquiry and NOS: (explain where and how in the lesson your NOS, NOSI, and science practices expected outcomes are explicitly addressed.)
During the data collection activity, I will emphasis the types of data collection: qualitative and quantitative. And the importance of both types of data sources. I will further explain that the way we analyze and interpret our data creates evidence that supports our guiding question.
Students will also learn that the procedures may be given but not all groups plant beds will look the same. And lastly conclusions are based upon the data collected and how the data was analyzed and interpreted into evidence.

Materials required:

- plants
- field notebooks
- soil
- gardening gloves

- pots
- tags for plants
- mini shovel
- ipads

Safety Concerns:

- Be respectful of classroom and classmates
- Inside voices
- Walking feet at all times
- No horseplay
- Goggles to be worn at all times during investigation
- No eating, drinking or consuming any materials in lab, unless instructed otherwise.
- Clean up; all materials should be back in Ms. Sureka's room.
- HAVE FUN!

Section of Lesson	**Time estimate**	**Teacher Guide** (what is the teacher doing)	**Planned questions, activities, & assessments**	**Student guide** (what are the students doing)
Opening	15 mins	*Ice Breaker* *Discuss with class how same guiding question can lead to different methods or procedures BUT then create similar conclusions.*	**Show a picture of a chocolate chip cookie.** **NOSI**: Pose the question how would you make a chocolate chip cookie? What is your method? Is yours the same as your groupmates? Discuss how we may have the same guiding question different methods but can still come up with the same conclusions.	Students participate in ice breaker activity. Students are participating in discussion, sharing their ideas.

Body	10min 20min	Discuss types of data collection. Remind students the plants that they planted today are for learning how to collect qualitative and quantitative data. I will be moving through the class observing the students and asking questions as they plant.	**Show class a picture of different plants. What do you observe? What kind of data could you collect?** What is qualitative data? What is quantitative data? Why are both types of data useful? "How do we know the plants are growing? What kind of DATA can we collect? Remind the class that data is NOT evidence yet. [**NOSI**] While in Mrs. Taylor's room remind students that they need to collect both quanti-	Students will work in groups. Students sharing ideas. And giving examples of types of data. Students will be observing and col-

		Going to Mrs. Taylor's room to collect data. Help students with data collection.	tative ad qualitative data about their plants.	lecting data
Closing	15 mins	*Lead students in discussion* *What is an observation? What is an inference?*	"What data should we collect about our plants?" "Is our data evidence yet? What is evidence?" "Why is evidence important?" **[NOSI]** What type of information did you use to make your decisions on what type of data to collect? [what students knew about the process]. Why didn't everyone do it the same way? [different experiences and expectations] How do scientists' and engineers' experiences and expectations influence how they do science? [make decisions based on what they know and think is important....This is subjectivity]	Class discussion

Extension activities (plans for early fin-ishers)		*Walking around the classroom, helping with data collection.*	Have students who finish early help with clean up.	Students help with clean up.
Assessment plans Exit Slip: Answer 3 group dynamic questions.				

Name of Lesson: Lesson 4 What plants grow in GA?			**Prepared by:** Carmen Carrion
Resource:			**Date: March 2018**
Topic: Investigat-ing	**Grade Level: 6th**	**Total time estimate: 100 minutes**	

Connections to NGSS:

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Overview/ Purpose/Assumptions:

During this lesson students investigate what types of plants can grow in Ga. These will be plants that students can purchase and then plant in their garden plots. Students will see that not all plants can grow in Ga weather. Student will also use the information that they gathered in lesson 2 “surveying the land” to help them investigate which plants will grow best in their garden plots..

Content Learning Outcomes:

Students will be able to identify plants to grow in their gardens.

NOSI Learning Outcomes:

Scientific investigations all begin with a question and do not necessarily test a hypothesis.
Inquiry procedures are guided by the question asked.
All scientists performing the same procedure may not get the same results.
Research conclusions must be consistent with the data collected.
Explanations are developed from a combination of collected data and what is already known.

Science Practices Outcomes:

Asking questions and defining problems.

Planning and carrying out investigations.

Obtaining, evaluating, and communicating information.

Constructing explanations.

Connections to Inquiry and NOSI: (explain where and how in the lesson your NOS, NOSI, and science practices expected outcomes are explicitly addressed.)

Before students have ipads I will remind them what their guiding question is. I will ask students why it is important to know where their garden plots are located before deciding what plants to plant.

Materials required:

- Field notebooks
- ipads

Safety Concerns:
None

Section of Lesson	Time estimate	Teacher Guide (what is the teacher doing)	Planned questions, activities, & assessments	Student guide (what are the students doing)
Opening	15 mins	*Ice Break* *Leading the students in discussion*	Show students pictures of engineering master pieces ex, coliseum and large fields and orchards of fruits an vegetables. “Do you think this was thrown together?” “what had to be done”	Students participate in ice breaker activity. Students are participating in discussion, sharing their ideas
Body	40 mins	Analyzing and Synthesizing Data Justifying what plants to grow in your garden	Look back at your previous lesson, *Lesson 2 Surveying the land*. Use the data about the group’s garden plot location and knowledge about the soil to decide what plants will grow best in your group’s plot. What data did you find from analyzing the surveying land data? How can you combine your soil data with your surveying data? Synthesize your group’s data. What does this data tell you? Now in your groups, research types of plants that can be grown in your garden plot using the data you have collected	Groups are looking at their previous data to help them understand what their garden plots’ climate will be in March.

	20min	Ask groups about their choices. Walking around and seeing how students are researching about plants. ***-Allow students to make guesses of what they think are the best plants to grow and have them write them in their field note-books.***	about soil and surveying the land. What plants have you chosen? Why have you chosen these plants? What evidence supports why these plants will grow in your group's plot? Have student write in field notebooks notes about the area. What kind of plants can we plant in our garden? Can we plant anything? Why or why not? What are key words or phrases to use when searching for plants to plant?	Have student answer prompts in their field notebooks One member from each group will present their list of plants that will grow well in Ga. Each plant chosen must have an explanation why it was chosen. Students using ipads to investigate plants to plant.
Closing	25 mins	*Lead students in discus-sion*	Have each group present their findings from their exploration. -This will be done on the white board via a table for plants. Students will explain why	During discussion, students should present on what plants to plant.

		What was our guiding question when investigating plants? *How do we know when to plant? What evidence do we have?*	they chose those plants "What evidence do you have that supports your plants will grow outside in Ga in the spring?" "What is evidence?" "Why is evidence important?" **[NOSI]** "Why are explanations needed? What do they show?" Explanations are developed from a combination of collected data and what is already known.**[NOSI]** What type of information did you use to make your decisions? [what students knew about the process]. Why didn't everyone do it the same way? [different experiences and expectations] How do scientists experiences and expectations influence how they do science? [make decisions based on what they know and think is important....This is subjectivity. This allows for scientists and engineers to perform investigations in different sequence and steps. We all have our own approach to tackle a problem.	
Extension activities		*Walking around the classroom, monitoring*		Students work individually on the ipads, while other students finish.

(plans for early fin-ishers)		*students researching on the ipads.*		
Assessment plans Exit Slip: Answer 3 group dynamic questions.				

Name of Lesson: Lesson 5 How to Engineer a garden from recyclables? Part 1			**Prepared by:** Carmen Carrion
Resource:			**Date: February**
Topic: Engineer-ing design	**Grade Level: 6th**	**Total time estimate: 55 min**	**1 class period**

Connections to NGSS:

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS- ETS1-4 Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. (Create a model that give the most effective and efficient solution.)

Georgia Standards of Excellence

S6CS1. Students will explore the importance of curiosity, honesty, openness, and skepticism in science and will exhibit these traits in their own efforts to understand how the world works.

a. Understand the importance of—and keep—honest, clear, and accurate records in science. b. Understand that hypotheses are valuable if they lead to fruitful investigations, even if the hypotheses turn out not to be completely accurate descriptions.

S6CS5. Students will use the ideas of system, model, change, and scale in exploring scientific and technological matters.

a. Observe and explain how parts are related to other parts in systems such as weather systems, solar systems, and ocean systems including how the output from one part of a system (in the form of material, energy, or information) can become the input to other parts. (For example: El Nino's effect on weather)

S6CS9. Students will investigate the features of the process of scientific inquiry.

Students will apply the following to inquiry learning practices:

a. Scientific investigations are conducted for different reasons. They usually involve collecting evidence, reasoning, devising hypotheses, and formulating explanations.

b. Scientists often collaborate to design research. To prevent bias, scientists conduct independent studies of the same questions.

c. Accurate record keeping, data sharing, and replication of results are essential for maintaining an investigator's credibility with other scientists and society.

d. Scientists use technology and mathematics to enhance the process of scientific inquiry.

Overview/ Purpose/Assumptions:

During this lesson student's will create a design of what their recyclable garden will look like based on the constraints and materials they have to build with. Groups will have to work together to design an optimal garden for construction.

Content Learning Outcomes:

Students will be able to identify how constraints and limitations help engineers figure out how to design solutions.

NOSI Learning Outcomes:

Scientific investigations all begin with a question and do not necessarily test a hypothesis.
Inquiry procedures are guided by the question asked.
There is no single set or sequence of steps followed in all investigations.

Science Practices Outcomes:

- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
- Asking questions and defining problems in grades 6–8 builds on grades K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.
- Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. (MS-ETS1-1)
- Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs. (MS-ETS1-4)

Connections to Inquiry and NOS: (explain where and how in the lesson your NOSI, and science practices expected outcomes are explicitly addressed.)This lesson will clearly demonstrate inquiry and allow the students to create their own gardens from recyclable materials. By doing so I will demonstrate the subjective nature and the use of creativity within the investigation process, specially design. Furthermore, I will explain how there is no single set or sequence of steps followed in all investigations. And lastly their design is guided by the question asked.

During the discussion I will remind students about the subjectivity of science as well as how creativity and imagination are used throughout an investigation.

Materials required:

- Butcher paper
- Markers

Safety Concerns:

- Be respectful of the outdoors and classmates
- Inside voices
- Walking feet at all times
- No horseplay
- No eating, drinking
- All materials need to stay in Mrs. Taylor's room
- Clean up; all materials should be back in Mrs. Taylor's room

Section of Lesson	Time estimate	Teacher Guide (what is the teacher doing)	Planned questions, activities, & assessments	Student guide (what are the students doing)
• HAVE FUN!				
Opening	10 mins	*Show picture of different gardens*	Show students picture of different gardens. Explain to students the differences in the gardens BUT remind students that the gardens all have the same purpose, to grow plants! How do you design an engineering project? What steps are involved? Why is it important to have these steps? Why is it important pilot a design?	Students participate in activity. Students are participating in discussion, sharing their ideas
Body	30min	Helping each group design their gardens. I will discuss modeling. -What is a model and how is it useful? -Ask for and/or Give examples of models	Ask students what is our guiding question? How did your guiding question help you decide what to build? I want students to understand that they are creating a small model with their recyclable gardens. Their materials that they have dictates how they sketch their designs.	Students are sketching and designing in their groups.

		Give students a list of construction materials made out of recyclables. I will also ask the students about planning and organizing, Point out- many students have the same guiding questions BUT each group is making different designs for their gardens.	From this list students can get an idea of what limitations and constraints they may have when sketching and designing. Students need to realize that models and investigations are not thrown together. They take time and must be planned out. (NGSS) There is no single set or sequence of steps followed in all investigations. Inquiry procedures are guided by the question asked. All scientists performing the same procedure may not get the same results. All scientists and engineers may have the same guiding question but may use different methods or designs to answer their guiding question. **[NOSI]**	Students are asking questions to each other about their sketches. Have students discuss what their guiding question is and how this question influenced their planning and design. Students are designing and sketching.
Closing	15 mins	*Lead students in discussion* *Will discuss how science is creative and uses imagination. Point out*	I will ask students to go around and view each other's work. Remind students that each group may have a different or similar guiding question.	During discussion, students should present on their recyclable gardens. Explaining to us why they designed the garden in the manner that they did, and what materials will they use and why.

		to students to look at their different gardens. *Discuss how the explanations of their designs/models are based of evidence they have researched.*	Ask- how does this guiding question affect how each group engineered their gardens. Have students explain to me what evidence did they use to justify why they are designing their garden in a certain way.	
Extension activities (plans for early finishers)		*Can go collect data about their plants.*	Have students who finish early collect data on their groups plants.	Students can go collect data on plants.
Assessment plans: Take exit slip- 3 questions about group dynamics.				

Name of Lesson: Lesson 5 How to Engineer a garden from recyclables? Part 2			**Prepared by:** Carmen
Resource:			**Date: February**
Topic: Engineering evaluation	**Grade Level: 6th**	**Total time estimate: 55min**	

Connections to NGSS:
MS-ETS1-1.- Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. Students must be able to explain what they are investigating and what limitations they are working with.

MS-ETS1-2.- Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. Students in groups must evaluate each other's designs to decide if their design aligns with their design.

Overview/ Purpose/Assumptions: During this lesson students will be evaluating each groups sketched designs to decide if any revisions or changes should be made before construction. The class as a group will decide which design will be constructed.
Content Learning Outcomes: Students will be able to evaluate and use evidence to defend their garden engineering designs.
NOSI Learning Outcomes: Inquiry procedures are guided by the question asked. All scientists performing the same procedure may not get the same results. Inquiry procedures can influence results or design.
Science Practices Outcomes: Planning and carrying out investigations. Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation. Constructing explanations and designing solutions in 6–8 builds on K– 5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories. Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints. Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and retesting. Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.
Connections to Inquiry and NOSI: (explain where and how in the lesson your NOS, NOSI, and science practices expected outcomes are explicitly addressed.) During the engineering design activity I will discuss with students how to evaluate one another's garden inquiry investigation designs. During the debrief students will learn that they need evidence to support their reasoning of why their designs look the way they

do.

Materials required:

- Butcher paper
- Markers
- Post-it notes

Safety Concerns:

- Clean up; all materials should be back on tables, tables should be returned to their original spots, materials properly put away in Mrs. Taylor's room.
- HAVE FUN!

Section of Lesson	**Time estimate**	**Teacher Guide** (what is the teacher doing)	**Planned questions, activities, & assessments**	**Student guide** (what are the students doing)
Opening	15 mins	*Ice Breaker:* *Pose three questions to students.*	Can groups have the same guiding question but create different procedures? Can groups have the same guiding questions, same procedures and still come up with a different design for their recyclable garden? Why do we need to evaluate the designs your groups sketched the previous class? What does this evaluation do? Why is it important?	Students participate in ice breaker activity. Students are participating in discussion, sharing their ideas.
Body	10 mins	Discuss how the guiding question is what drives helps drive their designs.	All investigations are driven by questioning. "What is your groups guiding question?"	Students are looking over their sketches.

	10 mins	Point out that some of may have different designs even though everyone has the same guiding question. Go over how class will have a "silent critique". All students using post-its will use leave a critique on each groups garden design.	**After looking over designs:** I will ask "how can you evaluate your groups design. Do think everything is perfect or is there room for improvement?" "What EVIDENCE do you have?" I will ask each group to look for evidence to support their projects designs. I hand students post-its. They walk around leaving critiques on post-its, which are then placed on the various groups garden designs.	Students evaluating designs. Using evidence to explain which are better designs. Students are walking around writing on post its and leaving written critiques on the garden designs.
Closing	20 mins	*Lead students in discussion*	I explain to groups that they may make changes to their design before the class	Students are making changes to their

		After the "silent critique" groups may make any changes to their designs. I choose one person from each group to explain the final design that they chose and tell us why they chose it. *The entire class will vote on one final design.*	votes. Students will be asked to explain their designs and tell me how they evaluated the designs in their groups. *I administer a class vote to help decide which garden design the class will construct.*	designs by using the critiques made by their classmates. During discussion, students should present on their garden engineering design explaining with evidence and reasoning why they designed the garden with the materials they have available. *Students will vote on which group design the class will construct.*
Extension activities (plans for early finishers)		*Walking around the classroom, assessing students finishing up designing.*	Students may go collect data on the Wisconsin fast plants.	May use mini ipads to take data.
Assessment plans Exit Slip: Answer 3 group dynamic questions.				

Name of Lesson: Lesson 5 How to Engineer a garden from recyclables? Part 3			**Prepared by:** Carmen
Resource:			**Date: February**
Topic: Engineering Construction	**Grade Level: 6th**	**Total time estimate: 150min**	

Connections to NGSS:

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Overview/ Purpose/Assumptions:

During this lesson students will begin constructing the garden design that the class voted on.

Content Learning Outcomes:

Students will be able to evaluate and use evidence to defend the chosen class garden design.

NOSI Learning Outcomes:

Inquiry procedures are guided by the question asked.
Inquiry procedures can influence results.

Science Practices Outcomes:

Constructing explanations and designing solutions:

Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system.

Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.

Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re- testing.

Engaging in argument from evidence

Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.

Connections to Inquiry and NOSI: (explain where and how in the lesson your NOS, NOSI, and science practices expected outcomes are explicitly addressed.)
During the engineering design activity I will discuss how in the last class period we evaluated each groups' garden engineering designs and as a class we have chosen one design to construct. During the debrief students will learn that they need evidence to support their reasoning.

Materials required:

- Wood
- Screws
- Nails
- Power drill
- Twine
- String
- Chicken wire
- Plants
- Soil
- Gardening tools

Safety Concerns:

- Be respectful when building
- No using the power drill
- Must ask permission to use tools
- No horseplay
- Goggles to be worn at all times during construction
- No eating, drinking or consuming any materials during construction.
- All building materials need to stay on tables, unless in use.
- <u>Clean up</u>; all materials should be back on tables, tables should be returned to their original spots, materials properly put away in Mrs. Taylor's room.
- HAVE FUN!

Section of Lesson	**Time estimate**	**Teacher Guide** (what is the teacher doing)	**Planned questions, activities, & assessments**	**Student guide** (what are the students doing)
Opening	10 mins	*Ice Breaker:*	Have group whose design won the vote	Students participate in ice breaker

		Which group design was voted to construct?	present and explain the design to the class.	activity.
Body	120 mins	Discuss how the guiding question is what drives their construction especially their design. Go outside with class! Go over lab safety for construction.	All investigations are driven by questioning. "What is your groups guiding question?" "What are your groups procedures?" "Is it ok for groups to have similar guiding questions or procedures? Assisting students in constructing the class design.	Discussing answers as a class. Go outside! Begin construction. Students are building and constructing the class design.
Closing	20 mins	*Back inside* *Lead students in discussion* *Explain how the class had the same guiding question, BUT each groups created different*	Back inside. Students will be asked to explain how scientists and engineers can use different procedures and methods BUT still come up with similar solutions. [NOSI] How does the guiding question relate to the conclusions or solutions at the end of an	Back inside. Students are participating in discussion.

		designs, BUT how the groups came together to the same design.	investigation? [NOSI]	
Extension activities (plans for early fin-ishers)		*Walking around the classroom, assessing students finishing up construction.*	Students may go collect data on the Wis-consin fast plants.	May use mini ipads to collect data.
Assessment plans Exit Slip: Answer three group dynamic questions.				

Appendix B: Lesson Worksheets

Below are the various worksheets that align with specific garden lessons. Each lesson does not necessarily have a corresponding worksheet. Throughout the intervention participating students were asked to answer questions in their field notebooks rather than the student worksheets.

<u>Lesson 2.1 Surveying the land</u>

Worksheet 2.1

Group # **Period #**

Observation data:

How does the plot area look?

How does the ground feel?

How much sunlight, where, what part of day?

What else did you find?

What kind of pictures do you need to take and why?

Lesson 2.2 Soil Composition

Soil Composition Worksheet 2.2 :

Group # **Period #**

Please make observations of each soil sample. Remember to use your senses!

What is your guiding question?

OBSERVATIONS

Soil Sample 1:

Soil Sample 2:

Soil Sample 3

Explain why these are your observations?

How do these observations relate to data?

How do these observations and data relate to the guiding question?

What claim can you make about each soil sample? What evidence supports your claim?

Lesson 3.1 Soil Experiment Laboratory

Worksheet 3.1 Soil Experiment

Names: Date: Period: Group #:

The guiding question is:

Hypothesis 1: IF……

Hypothesis 2: IF……

The Test:

What is your proposed procedure:

What data will you collect?

How will you analyze it?

What is your Predicted result:

If Hypothesis 1 is true THEN….

If Hypothesis 2 is true THEN….

Place your ACTUAL COLLECTED DATA here:

Your ANALYSIS and INTREPREATION of the data here:

The CLAIM you make is:

What EVIDENCE are you using:

Your JUSTIFICATION of the evidence:

Lesson 3.2 Indoor Garden

3.2 Data Collection Worksheet **Group:** **Date:**

What is my guiding question?

What is your Hypothesis 1?

What is your Hypothesis 2?

Qualitative Data (Descriptions such as: color, shape, texture, categories, etc)

Plant A- 1)

2)

Plant B- 1)

2)

Plant C- 1)

2)

Plant D- 1)

2)

Plant E- 1)

2)

Quantitative Data (Quantities or measurements such as: height, amount, length, etc)

Plant A- 1)

2)

Plant B- 1)

2)

Plant C- 1)

2)

Plant D- 1)

2)

Plant E- 1)

2)

Lesson 5.1 Engineering Design

5.1 Planning your Design Worksheet

Each group will design a garden using recyclable materials. You may use the internet as a resource.

Ask yourself and your group these questions as you design…..

What kind of design does your group want?

Think about what kind of constraints your group may have?

What kind of materials will you use?

Why is it important to first design your garden?

Why do we not start constructing right away?

Make sure to write a few sentences explaining your group's garden design.

Lesson 5.2 Gallery Walk- Design Evaluation

Lesson 5.2 Evaluation of Design Worksheet

One member from each group must present and explain their design.

The class will then participate in a silent gallery walk. As you walk around use a post-it to leave one positive comment and one critical comment on each group's design.

Questions to ask yourself as you are evaluating other groups as well as your own group's design.

Why is this design the best?

What makes one design better than another design?

Why should the class have a first choice and a second choice?

After the gallery walk groups may look at their feedback from other groups and may make changes to their group's design.

5.3 Engineering and Construction

5.3 Construction of the Design Worksheet

The class will vote on one design before construction begins.

Ask yourself as you construct…

Did the chosen design work?

Is the class able to construct the garden?

Does the class need to rethink the design? If so why? What went wrong?

Do you think engineers have to try out several designs before choosing one that works best?

Conclusion: Once all parts of the garden are constructed, sit on the class picnic tables. A group discussion will begin about engineering design. Ask yourself why are designing, explaining, and evaluating crucial for good scientific practices?

Appendix C: Views about Scientific Inquiry Instrument

The following questions are asking for your views related to science and scientific investigations.
There are no right or wrong answers.
Please answer each of the following questions. You can use all the space provided to answer a question and continue on the back of the pages if necessary.

1. A person interested in birds looked at hundreds of different types of birds who eat different types of food. He noticed that birds who eat similar types of food, tended to have similar shaped beaks. For example, birds that eat hard-shelled nuts have short, strong beaks, and birds who eat insects have long, slim beaks. He wondered if the shape of a bird's beak was related to the type of food the bird eats and he began to collect data to answer that question. He concluded that there is a relationship between beak shape and the type of food birds eat.

a. Do you consider this person's investigation to be scientific? Please explain why or why not.

b. Do you consider this person's investigation to be an experiment? Please explain why or why not.

c. Do you think that scientific investigations can follow more than one method?

If no, please explain why there is only one way to conduct a scientific investigation.

If yes, please describe two investigations that follow different methods, and explain how the methods differ and how they can still be considered scientific.

2. Two students are asked if scientific investigations must always begin with a scientific question. One of the students says “yes” while the other says “no”. Whom do you agree with and why?

3. (a) If several scientists ask the ***same question*** and follow the ***same procedures*** to collect data, will they necessarily come to the *same conclusions*? Explain why or why not.

   (b) If several scientists ask the ***same question*** and follow ***different procedures*** to collect data, will they necessarily come to the same conclusions? Explain why or why not.

4. Please explain if “data” and “evidence” are different from one another.

5. Two teams of scientists are walking to their lab one day and they saw a car pulled over with a flat tire. They all wondered, “Are certain brands of tires more likely to get a flat?”

Team A went back to the lab and tested various tires’ performance on one type of road surfaces.

Team B went back to the lab and tested one tire brand on three types of road surfaces.

Explain why one team’s procedure is better than the other one.

6. The data table below shows the relationship between plant growth in a week and the number of minutes of light received each day.

   Given this data, explain which one of the following conclusions you agree with and why. Please circle one:

   a. Plants grow taller with more sunlight
   b. Plants grow taller with less sunlight
   c. The growth of plants is unrelated to sunlight

   Please explain your choice of a, b, or c below:

Minutes of light each day	**Plant growth-height (cm per week)**
0	25
5	20
10	15
15	5
20	10
25	0

7. The fossilized bones of a dinosaur have been found by a group of scientists. Two different arrangements for the skeleton are developed as shown below.

Figure 1 Figure 2

a. Describe at least two reasons why you think most of the scientists agree that the animal in *figure 1* had the best sorting and positioning of the bones?

b. Thinking about your answer to the question above, what types of information do scientists use to explain their conclusions?

8. (a) Models are widely used in science. What is a scientific model? Describe and give an example.

A scientific model is….

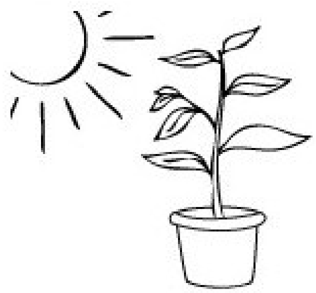
Give an example of a scientific model:

(b). How do scientists use scientific models?

Appendix D: Project 2061 Inquiry Practices Assessment Tool

1. A student wants to find out if a particular kind of plant grows better in the sun or in the shade. She has two identical plants. She places one plant in sand and sets the plant in the sunlight. She adds minerals and water to the sand.

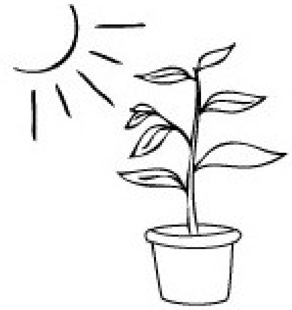
Sunlight



Water and minerals

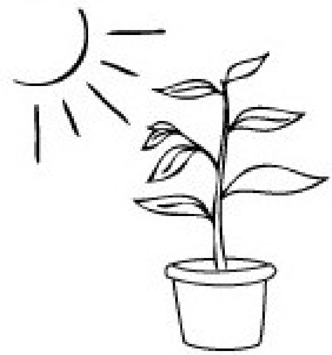
Which of the following conditions should she use for the second plant to determine the e**ff**ect of light?

A. Sunlight



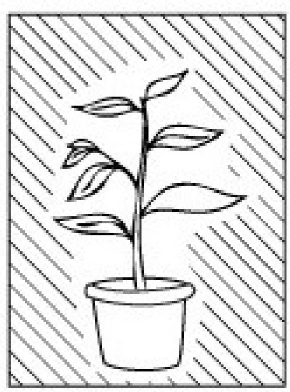
Water and minerals

B. Sunlight



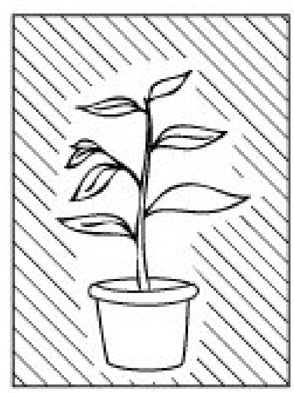
Water

C. Shade



Water and minerals

D. Shade



Water

2. A farmer thinks that type of soil and amount of water affect the growth of his carrot plants, and he wants to find out if he is right.

   The farmer first tests if the type of soil affects the growth of the carrot plants. He uses three different types of soil, and he places 10 carrot plants in each type of soil. He uses the same amount of water for all the plants.

   Why is it important to use the same amount of water for all the plants?

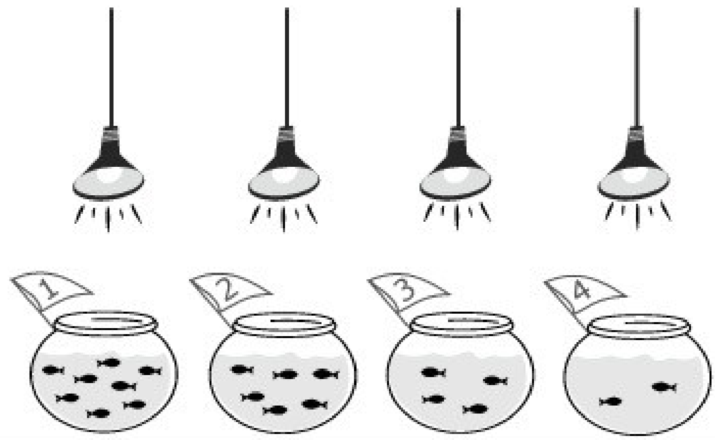
   A. By using the same amount of water, the farmer can learn about both the effect of the amount of water and the effect of the type of soil.

   B. By using the same amount of water, the farmer can learn about the effect of the amount of water.

   C. If he does not use the same amount of water, the farmer cannot learn about the effect of the type of soil.

   D. It is NOT important to use the same amount of water because the farmer is not testing the effect of the amount of water.

3. A student is interested in the behavior of fish. He has 4 fish bowls and 20 goldfish. He puts 8 fish in the first bowl, 6 fish in the second bowl, 4 fish in the third bowl and 2 fish in the fourth bowl. He places each fish bowl under light, he keeps the temperature at 75°F for all four bowls, and he observes the behavior of the fish.



Number of fish	8 fish	6 fish	4 fish	2 fish
Temperature	75°F	75°F	75°F	75°F

What can the student find out from doing just this experiment?

A. If the number of fish in the fish bowl affects the behavior of the fish.

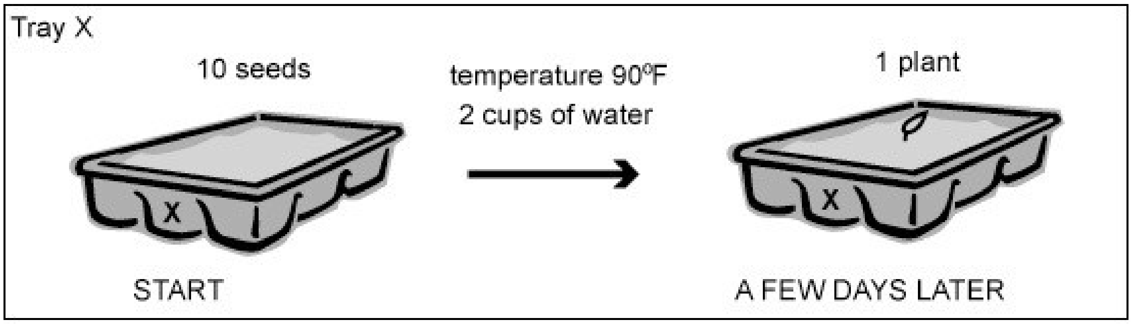
B. If the temperature of the fish bowl affects the behavior of the fish.

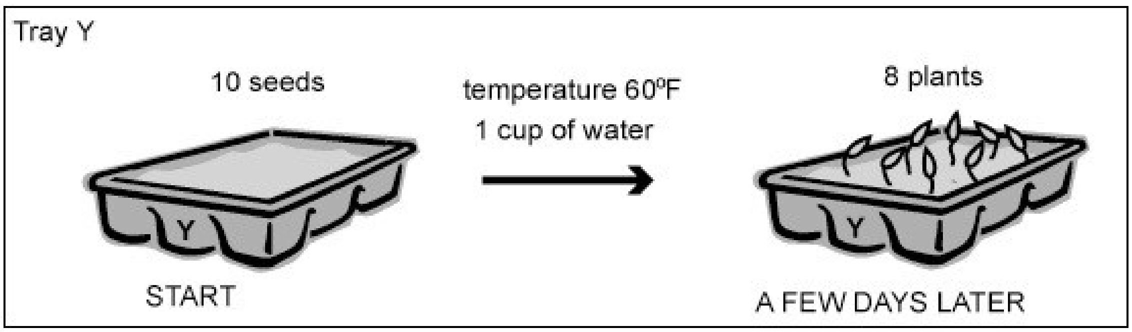
C. If the temperature of the fish bowl and the amount of light affect the behavior of the fish.

D. If the number of fish, the temperature, and the amount of light affect the behavior of the fish.

4. Students are planning to grow plants from seeds. They want to find out which of two temperatures, 60°F or 90°F, is better for growing these plants. They also want to find out if one cup of water or two cups of water is better for growing these plants.

They do the following experiment. They use two trays with identical soil and they plant ten seeds in each tray. They keep Tray X at 90°F and Tray Y at 60°F. They use two cups of water for Tray X and one cup of water for Tray Y. After a few days, they count how many plants are growing in each tray.





What can the students conclude from this experiment?

A. They can conclude that 60°F is better than 90°F for growing these plants.

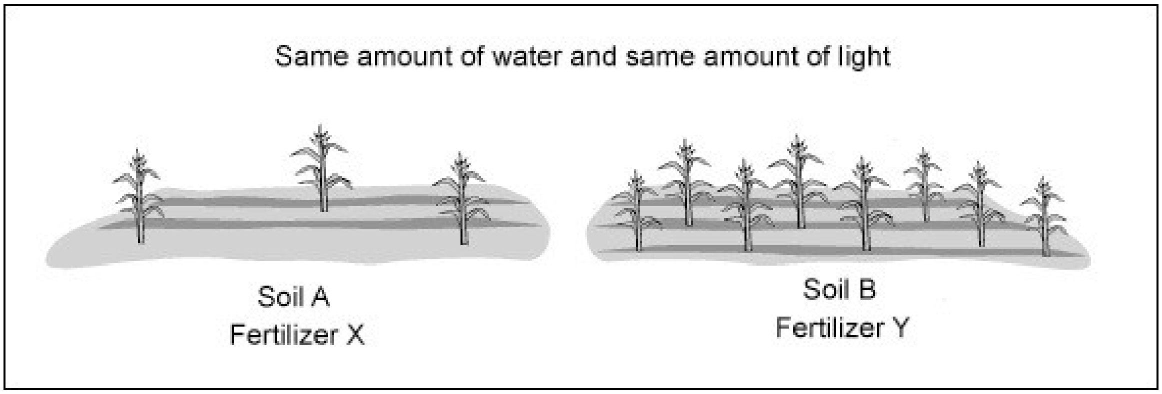
B. They can conclude that one cup of water is better than two cups of water for growing these plants.

C. They can conclude that 60°F is better than 90°F for growing these plants and that one cup of water is better than two cups of water for growing these plants.

D. It is not possible to conclude from this experiment if 60°F is better than 90°F for growing these plants or if one cup of water is better than two cups of water for growing these plants.

5. A farmer wants to find out which type of soil is best for growing his corn. He also wants to find out which type of fertilizer is best for growing his corn.

   He does the following experiment using two different types of soil and two different types of fertilizer:



   What can the farmer conclude from this experiment?

   A. He can conclude that Soil B is the best soil for growing his corn.

   B. He can conclude that Fertilizer Y is the best fertilizer for growing his corn.

   C. He can conclude that Soil B is the best soil for growing his corn and that Fertilizer Y is the best fertilizer for growing his corn.

   D. It is NOT possible to conclude from this experiment which soil is best for growing his corn or which fertilizer is best for growing his corn.

6. Which of the following statements about models is TRUE?

   A. Making models look more like the objects they represent always makes them better models.

   B. The main difference between a model and the object it represents is that the model is a different size.

   C. Models sometimes look quite different from the objects they represent.

   D. Models must be made of the same material as the objects they represent.

7. An engineer made a model of a ship to help him think about how it works. He made sure that some characteristics of the ship were accurately represented, but he did not include all of the ship's characteristics in his model. Is it okay that he ignored some of the ship's characteristics?

   A. It is okay, but only if he represented the characteristics that affect how the ship works, because models need to include the characteristics that are relevant to what is being studied.

   B. It is okay, but only if he represented the characteristics that affected whether the model looks like the ship, because models should look like the things that they represent.

   C. It is okay, but only if he represented the characteristics that people would be interested in knowing about, because models are only used to communicate information to others.

   D. It is not okay that he ignored some of the ship's characteristics. A model should be like the object it is representing in every way possible.

8. Which of the following could be represented with a model?

   A. An object, but not an event or process

   B. An event or process, but not an object

   C. An object, event, or process

   D. Neither an object, event, nor process

Answer key for the selected items

Question #	Item ID Number	Correct Answer
1	CV002003	C
2	CV014003	C
3	CV017002	A
4	CV020003	D

5	CV021003	D
6	M O025003	C
7	M O038004	A
8	M O079001	C

Appendix E: Observation Worksheets

All lessons were observed and the research was evaluated using this, Inquiry Analysis Tool (modified)(Volkmann & Abell, 2003). There are, a total of ten fidelity sheets filled out as the researcher taught all five garden inquiry lessons. Scanned copies of the fidelity sheets are below.

Date: 2-12-2018
Observer: Tia Hurley
Observed:
Location: A211

Inquiry Analysis Tool (modified)

(Volkmann & Abell, 2003)

Does the material/lesson:	Yes	No	N/A
1. Engage learners in scientifically oriented questions?			
• Do questions guide inquiry?	✓		
• Are questions relevant to students?	✓		
• Do students understand that investigations start with a guiding question?	✓		
2. Ask learners to give priority to data/evidence?			
• Do students understand the difference between data and evidence?	✓		
• Do students use their senses and instruments to collect data?	✓		
• Are students taught that different individuals can collect different data due to different methodologies?	✓		
• Do students have opportunities to decide what data to collect or how to collect it?			
• Do students evaluate the data they are gathering?	✓		
3. Encourage learners to create and design investigations from research?			
• Are students encouraged to design their own investigations?			✓
• Do students base their investigations from research?			✓
• Are students asked to explain their reasoning for the design of their investigation?			✓
• Do students plan and organize their investigations?			✓
4. Discuss with learners subjectiveness and tentativeness of science?	✓		
• Do students understand that each group may have different procedures and conclusions?	✓		
• Do students understand that creativity and imagination are used in science?	✓		
• Do students understand that science can change due to new discoveries and technology?			

5. Expect learners to communicate and justify their proposed designs, investigations, and explanations?			
• Do students have opportunities to discuss their ideas in small groups?	✓		
• Do students have opportunities to present their ideas through writing, drawing, or thinking?	✓		
• Do students have opportunities to present their ideas to other audiences? Ex) the class	✓		
6. Discuss with learners the importance of modeling in science.			
• Are students encouraged to create models?			✓
• Do students understand what is a scientific model and how it helps them learn new information?		✓	
• Do students practice modeling with their groups?			✓
• Do students create explanations using their models for reasoning?			✓

Date: 2/14/2018
Observer: Tia Hurley
Observed: Soil Sample test
Location: A 104

Inquiry Analysis Tool (modified)

(Volkmann & Abell, 2003)

Does the material/lesson:	Yes	No	N/A
1. Engage learners in scientifically oriented questions?			
• Do questions guide inquiry?	✓		
• Are questions relevant to students?	✓		
• Do students understand that investigations start with a guiding question?	✓		
2. Ask learners to give priority to data/evidence?			
• Do students understand the difference between data and evidence?	✓		
• Do students use their senses and instruments to collect data?	✓		
• Are students taught that different individuals can collect different data due to different methodologies?	✓		
• Do students have opportunities to decide what data to collect or how to collect it?			✓
• Do students evaluate the data they are gathering?	✓		
3. Encourage learners to create and design investigations from research?			
• Are students encouraged to design their own investigations?			✓
• Do students base their investigations from research?			✓
• Are students asked to explain their reasoning for the design of their investigation?			✓
• Do students plan and organize their investigations?			✓
4. Discuss with learners subjectiveness and tentativeness of science?			
• Do students understand that each group may have different procedures and conclusions?	✓		
• Do students understand that creativity and imagination are used in science?	✓		
• Do students understand that science can change due to new discoveries and technology?	✓		

yes awesome job w/using senses to collect Data on Soil samples

forth-coming students are informed of upcoming

5. Expect learners to communicate and justify their proposed designs, investigations, and explanations?			
• Do students have opportunities to discuss their ideas in small groups?	✓		
• Do students have opportunities to present their ideas through writing, drawing, or thinking?	✓		
• Do students have opportunities to present their ideas to other audiences? Ex) the class			✓
6. Discuss with learners the importance of modeling in science.			
• Are students encouraged to create models?			✓
• Do students understand what is a scientific model and how it helps them learn new information?		✓	
• Do students practice modeling with their groups?			✓
• Do students create explanations using their models for reasoning?			✓

Date: 2-16-18
Observer: Taylor
Observed: Cawrion
Location: CTMS - A104

Inquiry Analysis Tool (modified)

(Volkmann & Abell, 2003)

Does the material/lesson:	Yes	No	N/A
1. Engage learners in scientifically oriented questions?			
• Do questions guide inquiry?	✓		
• Are questions relevant to students?	✓		
• Do students understand that investigations start with a guiding question?	✓		
2. Ask learners to give priority to data/evidence?			
• Do students understand the difference between data and evidence?	✓		
• Do students use their senses and instruments to collect data?	✓		
• Are students taught that different individuals can collect different data due to different methodologies?	✓		
• Do students have opportunities to decide what data to collect or how to collect it?	✓		
• Do students evaluate the data they are gathering?	✓		
3. Encourage learners to create and design investigations from evidence?	✓		
• Are students encouraged to design their own investigations?			
• Do students base their investigations from evidence?	✓		
• Are students asked to explain their reasoning for the design of their investigation?	✓		
• Do students plan and organize their investigations?			✓
4. Discuss with learners subjectiveness and tentativeness of science?	✓		
• Do students understand that each group may have different procedures and conclusions?			✓
• Do students understand that creativity and imagination are used in science?			
• Do students understand that science can change due to new discoveries and technology?			✓

← In one group some students showed that they had different amounts of soil (variable) and so their data was not going to be correct. Their water was a constant (2003)

2-16-18
Taylor
Carrion

5. Expect learners to communicate and justify their proposed designs, investigations, and explanations?			
• Do students have opportunities to discuss their ideas in small groups?	✓		
• Do students have opportunities to present their ideas through writing, drawing, or thinking?			✓
• Do students have opportunities to present their ideas to other audiences? Ex) the class	✓		
6. Discuss with learners the importance of modeling in science.			
• Are students encouraged to create models?			✓
• Do students understand what is a scientific model and how it helps them learn new information?			✓
• Do students practice modeling with their groups?			✓
• Do students create explanations using their models for reasoning?			✓

Date: 2.23.18
Observer: S. Taylor
Observed: C. Carrion
Location: CTMS

Inquiry Analysis Tool (modified)

(Volkmann & Abell, 2003)

Does the material/lesson:	Yes	No	N/A
1. Engage learners in scientifically oriented questions?			
• Do questions guide inquiry?	✓		
• Are questions relevant to students?	✓		
• Do students understand that investigations start with a guiding question?	✓		
2. Ask learners to give priority to data/evidence?			
• Do students understand the difference between data and evidence?	Did not see that today		✓
• Do students use their senses and instruments to collect data?	✓		
• Are students taught that different individuals can collect different data due to different methodologies?			
• Do students have opportunities to decide what data to collect or how to collect it?	✓		
• Do students evaluate the data they are gathering?	✓		
3. Encourage learners to create and design investigations from research?			
• Are students encouraged to design their own investigations?		Students chose their own choice of soil.	
• Do students base their investigations from research?	✓		
• Are students asked to explain their reasoning for the design of their investigation?			✓
• Do students plan and organize their investigations?	✓		
4. Discuss with learners subjectiveness and tentativeness of science?			✓ not observed for this class.
• Do students understand that each group may have different procedures and conclusions?		not fully	
• Do students understand that creativity and imagination are used in science?			
• Do students understand that science can change due to new discoveries and technology?			✓

5. Expect learners to communicate and justify their proposed designs, investigations, and explanations?				Need to control the off task talking
• Do students have opportunities to discuss their ideas in small groups?	✓			
• Do students have opportunities to present their ideas through writing, drawing, or thinking?	✓			
• Do students have opportunities to present their ideas to other audiences? Ex) the class				
6. Discuss with learners the importance of modeling in science.			N/A	
• Are students encouraged to create models?			✓	
• Do students understand what is a scientific model and how it helps them learn new information?			✓	
• Do students practice modeling with their groups?			✓	
• Do students create explanations using their models for reasoning?			✓	

Suggestions:

- Get <u>all</u> students' attention prior to giving out directions to prevent the teacher from jumping in several times to get the students' attention. (Didn't want to interrup you several times)

Date: 2/26/2018
Observer: T. Hurley
Observed: Students collecting data on their plants (soil test w/ live organisms)
Location: Taylors Class A104

Inquiry Analysis Tool (modified)

(Volkmann & Abell, 2003)

Does the material/lesson:	Yes	No	N/A
1. Engage learners in scientifically oriented questions?			
• Do questions guide inquiry?	✓		
• Are questions relevant to students?	✓		
• Do students understand that investigations start with a guiding question?	✓		
2. Ask learners to give priority to data/evidence?			
• Do students understand the difference between data and evidence?	✓		
• Do students use their senses and instruments to collect data?	✓		
• Are students taught that different individuals can collect different data due to different methodologies?	✓		
• Do students have opportunities to decide what data to collect or how to collect it? Quantitative vs. Qualitative	✓		
• Do students evaluate the data they are gathering?	✓		
3. Encourage learners to create and design investigations from research?			
• Are students encouraged to design their own investigations?			✓
• Do students base their investigations from research?			✓
• Are students asked to explain their reasoning for the design of their investigation?			✓
• Do students plan and organize their investigations?			✓
4. Discuss with learners subjectiveness and tentativeness of science?	✓		
• Do students understand that each group may have different procedures and conclusions?			
• Do students understand that creativity and imagination are used in science?	✓		
• Do students understand that science can change due to new discoveries and technology?	✓		

awesome job #

very engaging Activity I really like how students worked on different activities @ different times.

5. Expect learners to communicate and justify their proposed designs, investigations, and explanations?			
• Do students have opportunities to discuss their ideas in small groups?	✓		
• Do students have opportunities to present their ideas through writing, drawing, or thinking?	✓		charting
• Do students have opportunities to present their ideas to other audiences? Ex) the class			
6. Discuss with learners the importance of modeling in science.			
• Are students encouraged to create models?	✓		
• Do students understand what is a scientific model and how it helps them learn new information?	✓		
• Do students practice modeling with their groups?	✓		
• Do students create explanations using their models for reasoning?	✓		

The small plants that they are observing are models of the larger gardens that will be planted by the students within the next couple of weeks

Date: 2/28/2018
Observer: Gulser
Observed: Carmen
Location:

Inquiry Analysis Tool (modified)

(Volkmann & Abell, 2003)

Does the material/lesson:	Yes	No	N/A
1. Engage learners in scientifically oriented questions?			
• Do questions guide inquiry?	✓		
• Are questions relevant to students?	✓		
• Do students understand that investigations start with a guiding question?	✓		
2. Ask learners to give priority to data/evidence?			
• Do students understand the difference between data and evidence?			
• Do students use their senses and instruments to collect data?	✓		
• Are students taught that different individuals can collect different data due to different methodologies?	✓		
• Do students have opportunities to decide what data to collect or how to collect it?	✓		
• Do students evaluate the data they are gathering?	✓		
3. Encourage learners to create and design investigations from research?			
• Are students encouraged to design their own investigations?			
• Do students base their investigations from research?			
• Are students asked to explain their reasoning for the design of their investigation?			
• Do students plan and organize their investigations?			
4. Discuss with learners subjectiveness and tentativeness of science?			
• Do students understand that each group may have different procedures and conclusions?	✓		
• Do students understand that creativity and imagination are used in science?			
• Do students understand that science can change due to new discoveries and technology?			

5. Expect learners to communicate and justify their proposed designs, investigations, and explanations? • Do students have opportunities to discuss their ideas in small groups?	✓		
• Do students have opportunities to present their ideas through writing, drawing, or thinking?	✓		
• Do students have opportunities to present their ideas to other audiences? Ex) the class	✓		
6. Discuss with learners the importance of modeling in science. • Are students encouraged to create models?			
• Do students understand what is a scientific model and how it helps them learn new information?			
• Do students practice modeling with their groups? • Do students create explanations using their models for reasoning?			

Date: 3/5/2018
Observer: Gulsen Leblebicioglu
Observed: Carmen
Location:

Inquiry Analysis Tool (modified)

(Volkmann & Abell, 2003)

Does the material/lesson:	Yes	No	N/A
1. Engage learners in scientifically oriented questions?			
• Do questions guide inquiry?	✓		
• Are questions relevant to students?	✓		
• Do students understand that investigations start with a guiding question?	✓		
2. Ask learners to give priority to data/evidence?			
• Do students understand the difference between data and evidence?	✓		
• Do students use their senses and instruments to collect data?	✓		
• Are students taught that different individuals can collect different data due to different methodologies?	✓		
• Do students have opportunities to decide what data to collect or how to collect it?	✓		
• Do students evaluate the data they are gathering?	✓		
3. Encourage learners to create and design investigations from research?			
• Are students encouraged to design their own investigations?	✓		
• Do students base their investigations from research?	✓		
• Are students asked to explain their reasoning for the design of their investigation?	✓		
• Do students plan and organize their investigations?			
4. Discuss with learners subjectiveness and tentativeness of science?			
• Do students understand that each group may have different procedures and conclusions?	✓		
• Do students understand that creativity and imagination are used in science?			
• Do students understand that science can change due to new discoveries and technology?			

5. Expect learners to communicate and justify their proposed designs, investigations, and explanations?			
• Do students have opportunities to discuss their ideas in small groups?	✓		
• Do students have opportunities to present their ideas through writing, drawing, or thinking?	✓		
• Do students have opportunities to present their ideas to other audiences? Ex) the class	✓		
6. Discuss with learners the importance of modeling in science.			
• Are students encouraged to create models?			
• Do students understand what is a scientific model and how it helps them learn new information?			
• Do students practice modeling with their groups?			
• Do students create explanations using their models for reasoning?			

294

Date: 3/6/18
Observer: S. Taylor
Observed: Ms. Carrion
Location:

Inquiry Analysis Tool (modified)

(Volkmann & Abell, 2003)

Does the material/lesson:	Yes	No	N/A
1. Engage learners in scientifically oriented questions?			
• Do questions guide inquiry?	✓		
• Are questions relevant to students?	✓		
• Do students understand that investigations start with a guiding question?	✓		
2. Ask learners to give priority to data/evidence?			
• Do students understand the difference between data and evidence?			
• Do students use their senses and instruments to collect data?	✓		
• Are students taught that different individuals can collect different data due to different methodologies?			N/A
• Do students have opportunities to decide what data to collect or how to collect it?			N/A
• Do students evaluate the data they are gathering?			N/A
3. Encourage learners to create and design investigations from research?			
• Are students encouraged to design their own investigations?			✓
• Do students base their investigations from research?	✓		
• Are students asked to explain their reasoning for the design of their investigation?		N/A	
• Do students plan and organize their investigations?	✓		
4. Discuss with learners subjectiveness and tentativeness of science?			✓
• Do students understand that each group may have different procedures and conclusions?		✓	not really
• Do students understand that creativity and imagination are used in science?			
• Do students understand that science can change due to new discoveries and technology?		✓	

[all the time allow students to come up with what ever ym are trying to ask]

Do this everyday so that students will remember their reason

5. Expect learners to communicate and justify their proposed designs, investigations, and explanations? • Do students have opportunities to discuss their ideas in small groups?	✓		
• Do students have opportunities to present their ideas through writing, drawing, or thinking?	✓		
• Do students have opportunities to present their ideas to other audiences? Ex) the class			✓
6. Discuss with learners the importance of modeling in science. • Are students encouraged to create models?		✓	
• Do students understand what is a scientific model and how it helps them learn new information?		✓	
• Do students practice modeling with their groups?			✓
• Do students create explanations using their models for reasoning?			✓

Date: 3/7/18
Observer: Tia Hurley
Observed: CARMEN CARRION
Location: A 104 CTMS

Inquiry Analysis Tool (modified)
(Volkmann & Abell, 2003)

Does the material/lesson:	Yes	No	N/A
1. Engage learners in scientifically oriented questions?			
• Do questions guide inquiry?	✓		
• Are questions relevant to students?	✓		
• Do students understand that investigations start with a guiding question?	✓		
2. Ask learners to give priority to data/evidence?			
• Do students understand the difference between data and evidence?	✓		
• Do students use their senses and instruments to collect data?	✓		
• Are students taught that different individuals can collect different data due to different methodologies?	✓		
• Do students have opportunities to decide what data to collect or how to collect it? • Do students evaluate the data they are gathering?	✓		
3. Encourage learners to create and design investigations from research?			
• Are students encouraged to design their own investigations?	✓		
• Do students base their investigations from research? • Are students asked to explain their reasoning for the design of their investigation?	✓		
• Do students plan and organize their investigations?	✓		
4. Discuss with learners subjectiveness and tentativeness of science?			
• Do students understand that each group may have different procedures and conclusions?	✓		
• Do students understand that creativity and imagination are used in science?	✓		
• Do students understand that science can change due to new discoveries and technology?	✓		

Students were very engaged in their learning, observations and analysis

5. Expect learners to communicate and justify their proposed designs, investigations, and explanations? • Do students have opportunities to discuss their ideas in small groups?	✓		
• Do students have opportunities to present their ideas through writing, drawing, or thinking?	✓		
• Do students have opportunities to present their ideas to other audiences? Ex) the class	✓		
6. Discuss with learners the importance of modeling in science. • Are students encouraged to create models?	✓		
• Do students understand what is a scientific model and how it helps them learn new information?	✓		
• Do students practice modeling with their groups?	✓		
• Do students create explanations using their models for reasoning?	✓		

charting :)

Think-pair share

awesome class

Date: 3/13/18
Observer: T. Hurley
Observed: C. Cannon
Location: A211-CTMS

Inquiry Analysis Tool (modified)

(Volkmann & Abell, 2003)

Does the material/lesson:	Yes	No	N/A
1. Engage learners in scientifically oriented questions?			
• Do questions guide inquiry?	✓		
• Are questions relevant to students?	✓		
• Do students understand that investigations start with a guiding question?	✓		
2. Ask learners to give priority to data/evidence?			
• Do students understand the difference between data and evidence?	✓		
• Do students use their senses and instruments to collect data?	✓		
• Are students taught that different individuals can collect different data due to different methodologies?	✓		
• Do students have opportunities to decide what data to collect or how to collect it?			
• Do students evaluate the data they are gathering?			
3. Encourage learners to create and design investigations from evidence?			
• Are students encouraged to design their own investigations?	✓		
• Do students base their investigations from evidence?	✓		
• Are students asked to explain their reasoning for the design of their investigation?	✓		
• Do students plan and organize their investigations?	✓		
4. Discuss with learners subjectiveness and tentativeness of science?	✓		
• Do students understand that each group may have different procedures and conclusions?	✓		
• Do students understand that creativity and imagination are used in science?	✓		
• Do students understand that science can change due to new discoveries and technology?			

3/13/18
T. Hurley
C. Carrion

5. Expect learners to communicate and justify their proposed designs, investigations, and explanations? • Do students have opportunities to discuss their ideas in small groups?	✓			Analyzing their comments
• Do students have opportunities to present their ideas through writing, drawing, or thinking?	✓			
• Do students have opportunities to present their ideas to other audiences? Ex) the class	✓			
6. Discuss with learners the importance of modeling in science. • Are students encouraged to create models?				Models were awesome
• Do students understand what is a scientific model and how it helps them learn new information?	✓			
• Do students practice modeling with their groups? • Do students create explanations using their models for reasoning?	✓			the students analyzed and critiqued each others Garden prototypes

Appendix F: Field Notes

Field notes were taken everyday lessons were taught. Field notes were taken to allow the research to make notes as lessons were going on. These notes informed the researcher of any changes that occurred during the lesson or future changes that could be made to future lessons. Field notes were hand written in a field notebook. Field notes were not transcribed into a digital form however the original field notebook may be produced if an individual asks to see the notes.

Appendix G: Student results to the VASI graphed

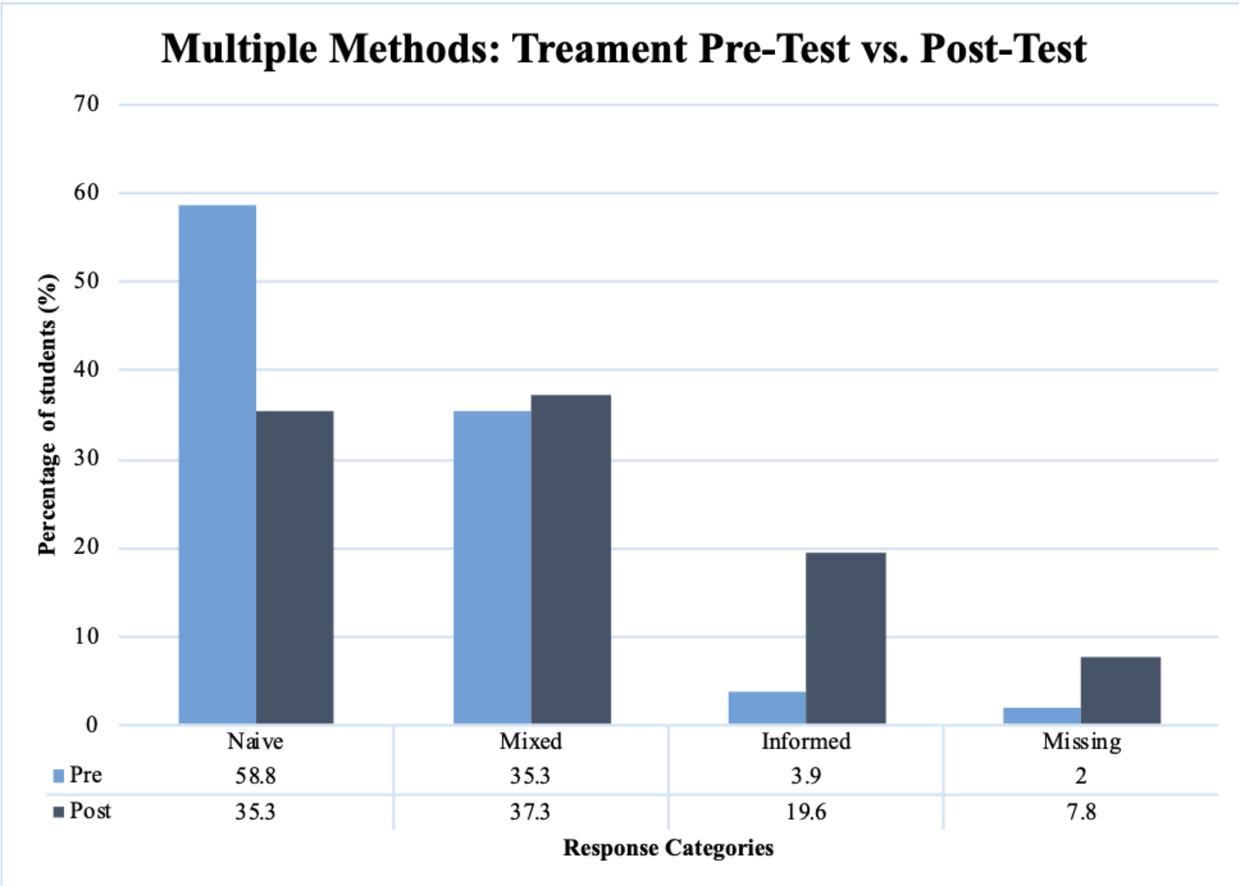


Figure 22. *Percentage of treatment group students pretests versus posttests for each response category for NOSI aspect Multiple Methods.*

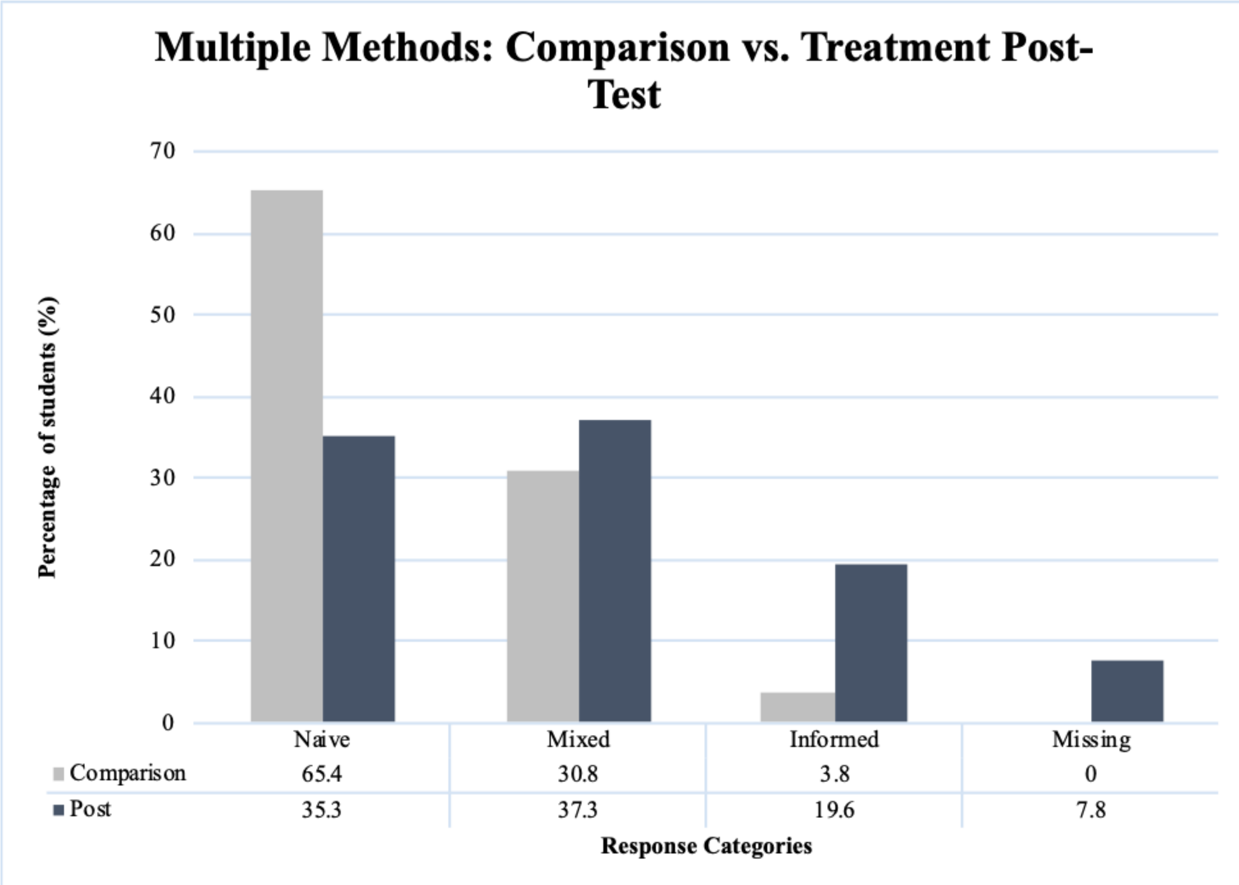


Figure 23. *Percentage of comparison group versus treatment group students' posttests for each response category for NOSI aspect Multiple Methods.*

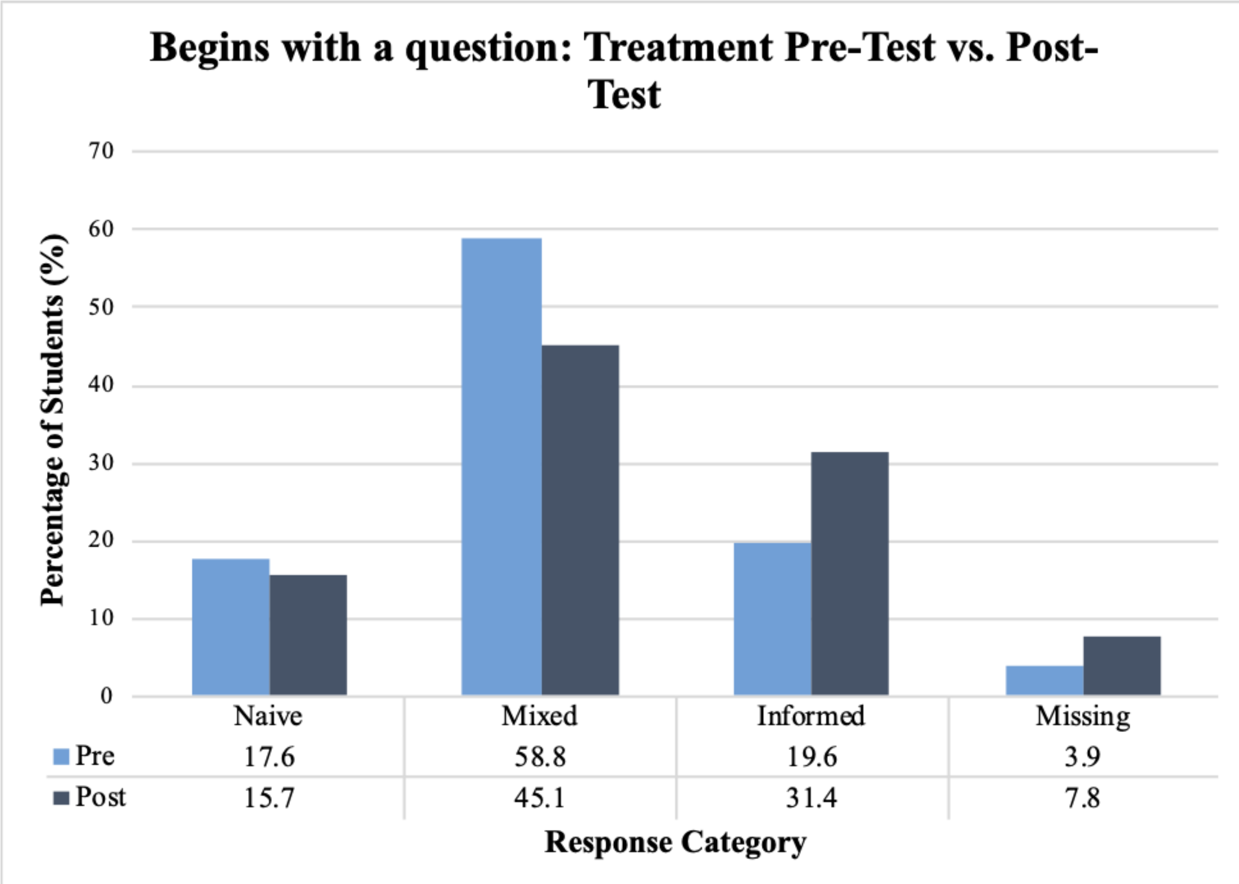


Figure 24. *Percentage of treatment group students pretests versus posttests for each response category for NOSI scientific investigations all begin with a question but do not necessarily test a hypothesis.*

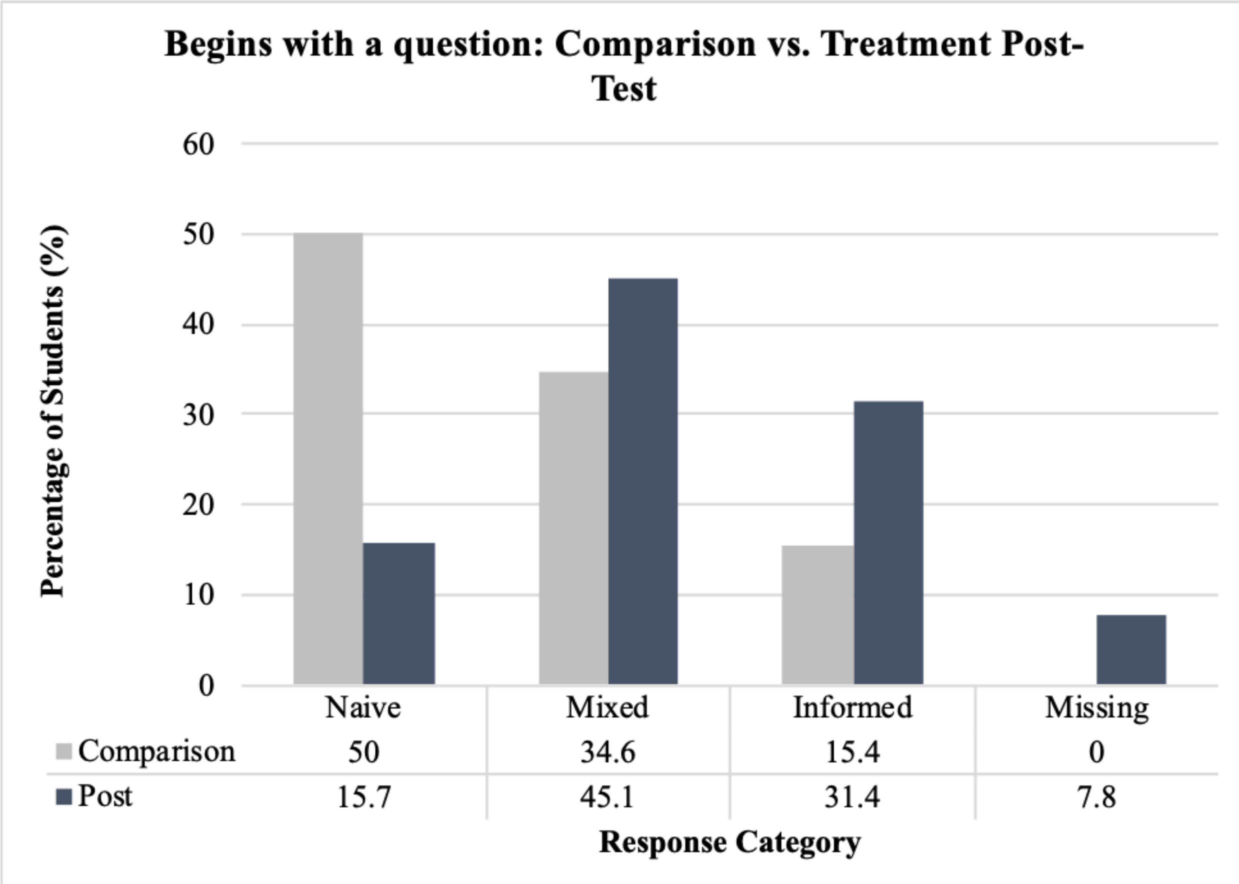


Figure 25. *Percentage of comparison group versus treatment group students' posttests for each response category for NOSI aspect scientific investigations all begin with a question but do not necessarily test a hypothesis.*

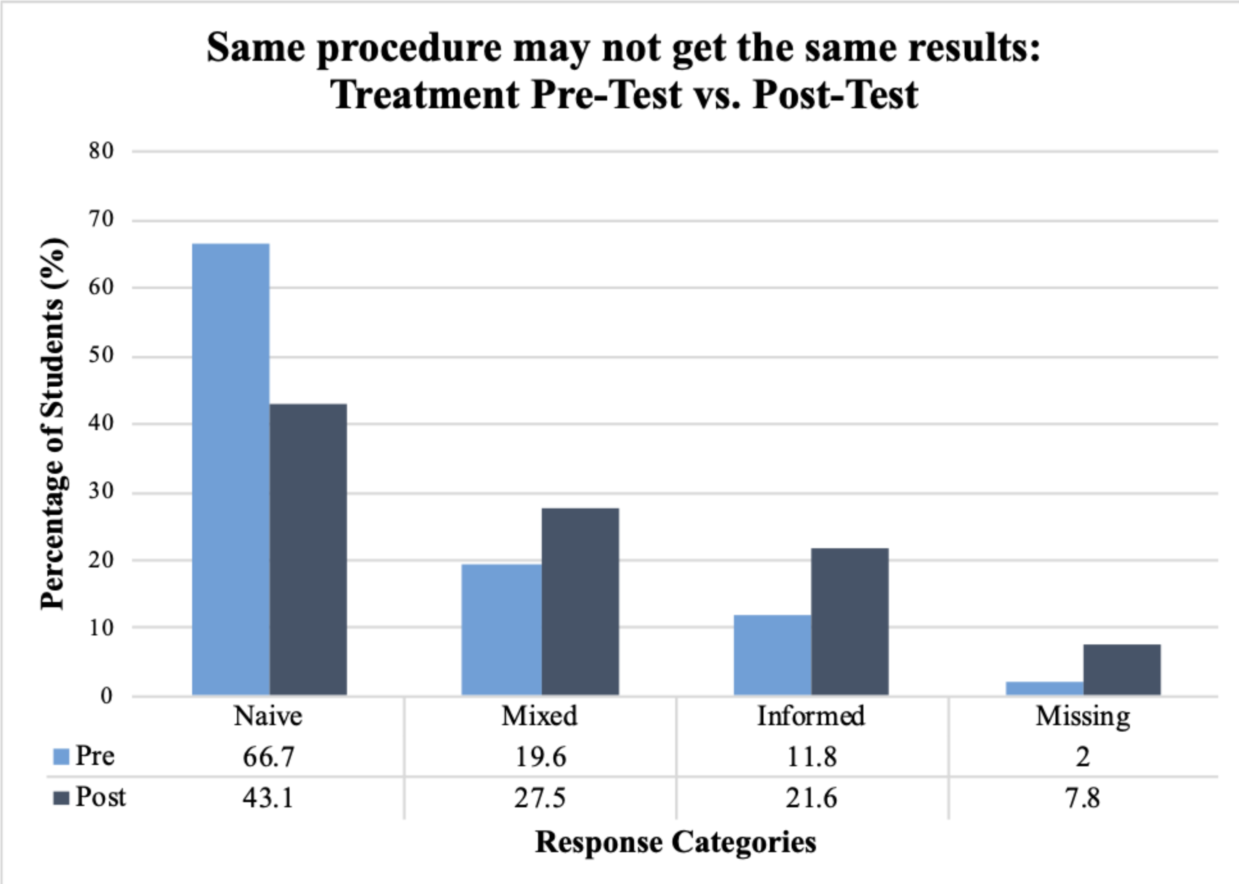


Figure 26. *Percentage of treatment group students' pretests versus posttests for each response category for NOSI aspect same procedure may not get the same results*

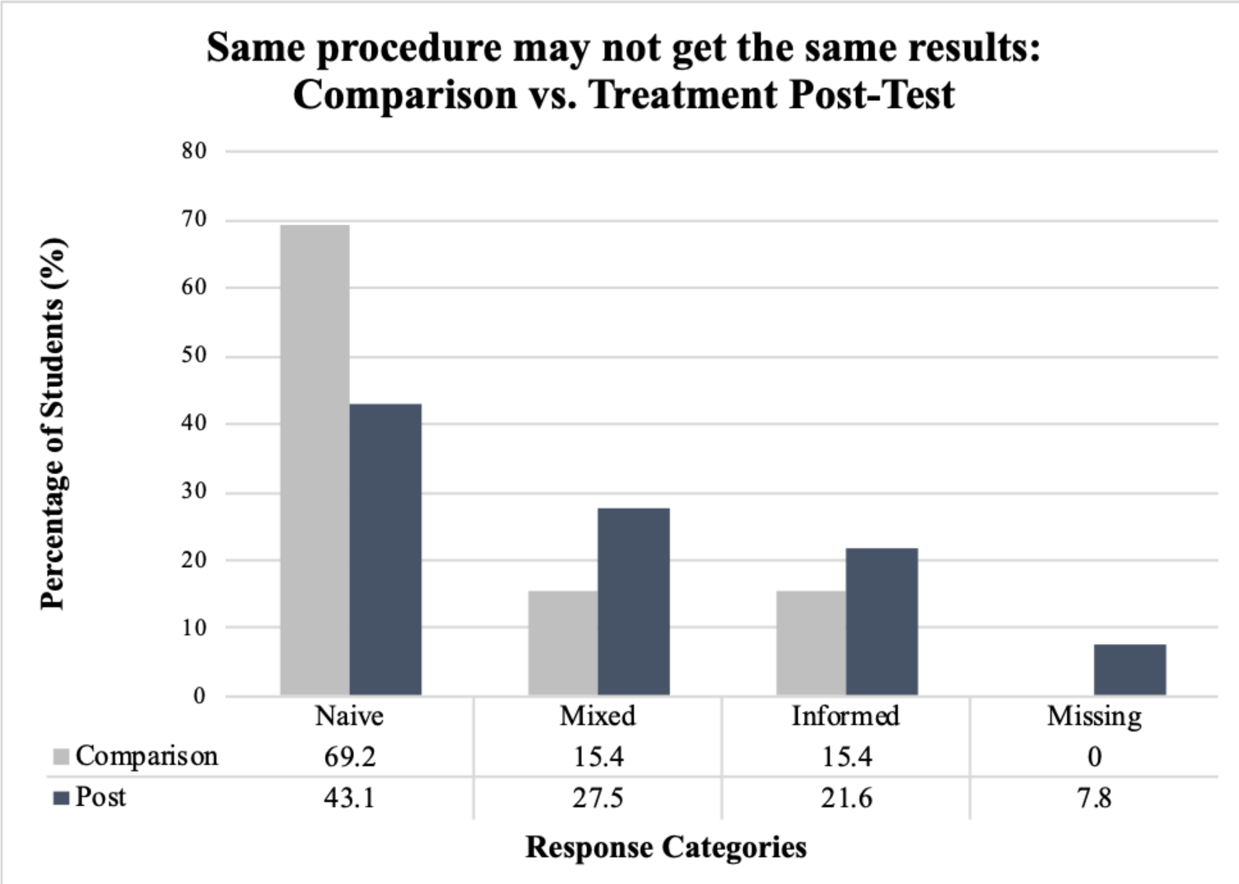


Figure 27. *Percentage of comparison group versus treatment group students' posttests for each response category for NOSI aspect same procedure may not get the same results.*

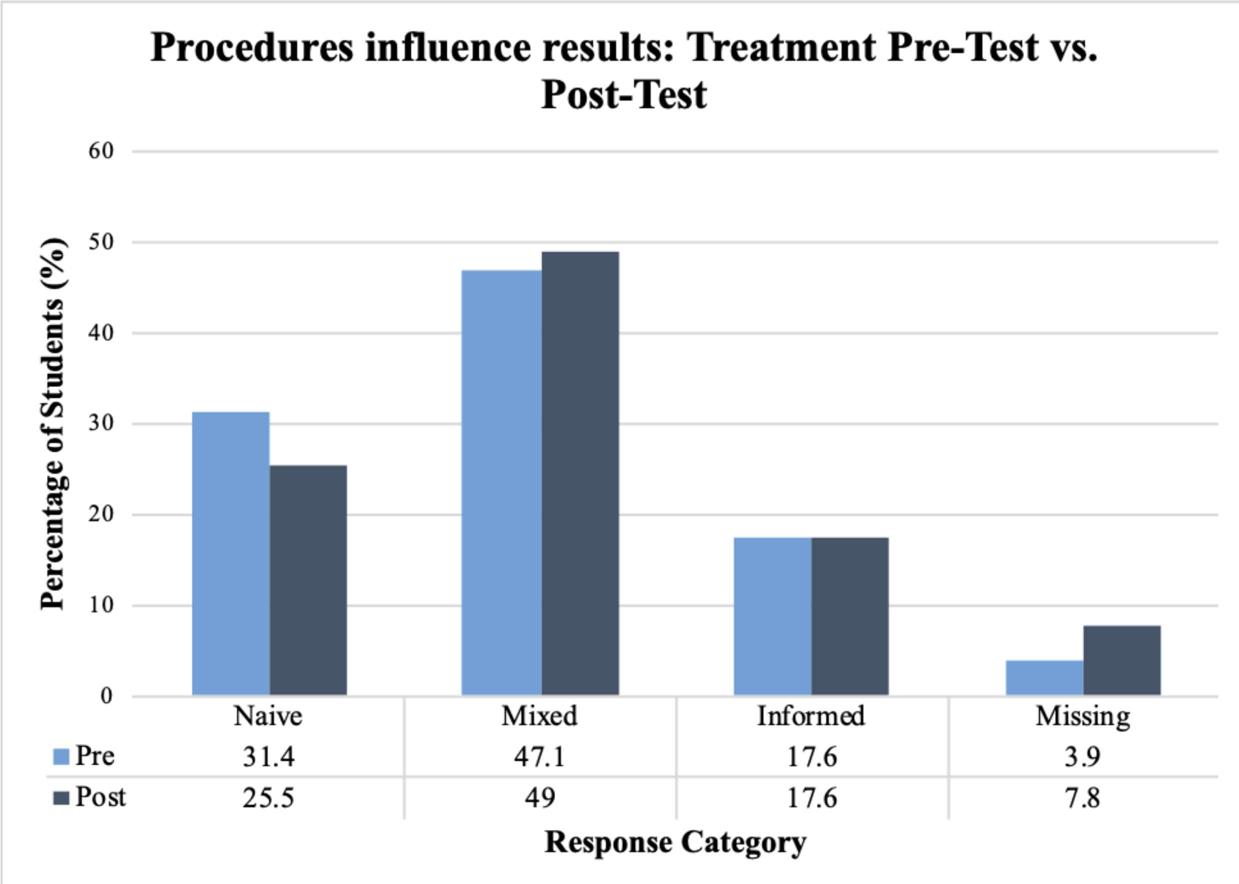


Figure 28. *Percentage of treatment group students' pretests versus posttests for each response category for NOSI aspect procedures influence results.*

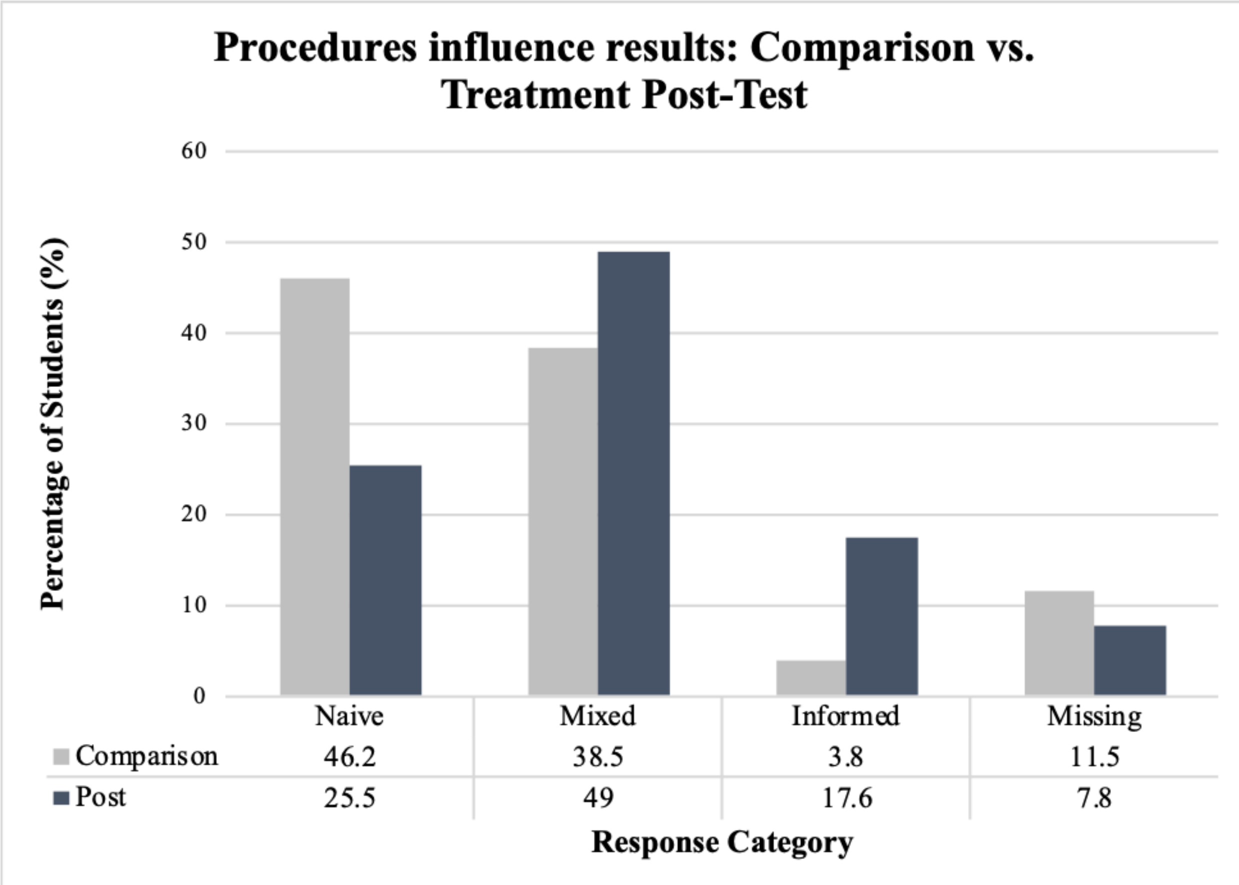


Figure 29. *Percentage of comparison group versus treatment group students' posttests for each response category for NOSI aspect procedures influence results*

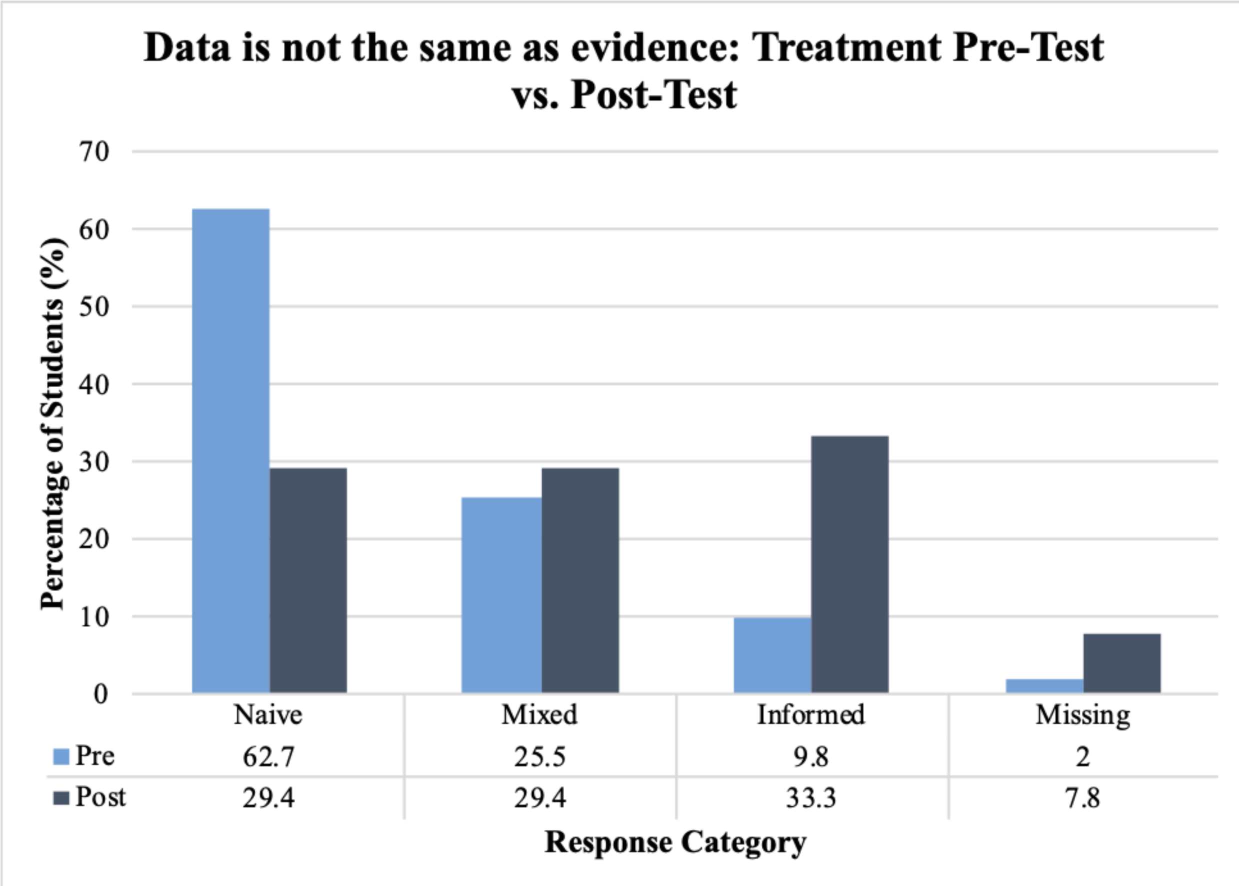


Figure 30. *Percentage of treatment group students' pretests versus posttests for each response category for NOSI aspect data are not the same as evidence*

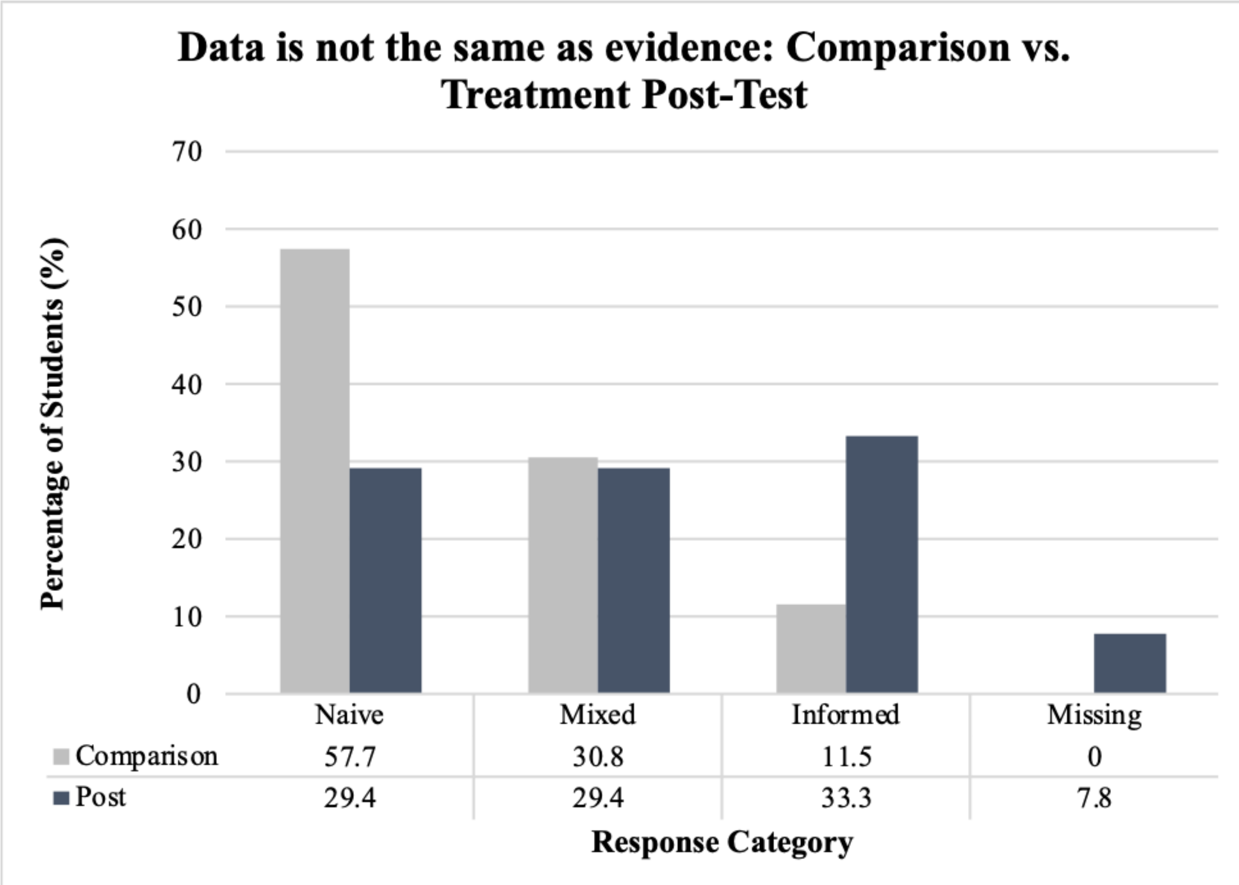


Figure 31. *Percentage of comparison group versus treatment group students' posttests for each response category for NOSI aspect data are not the same as evidence*

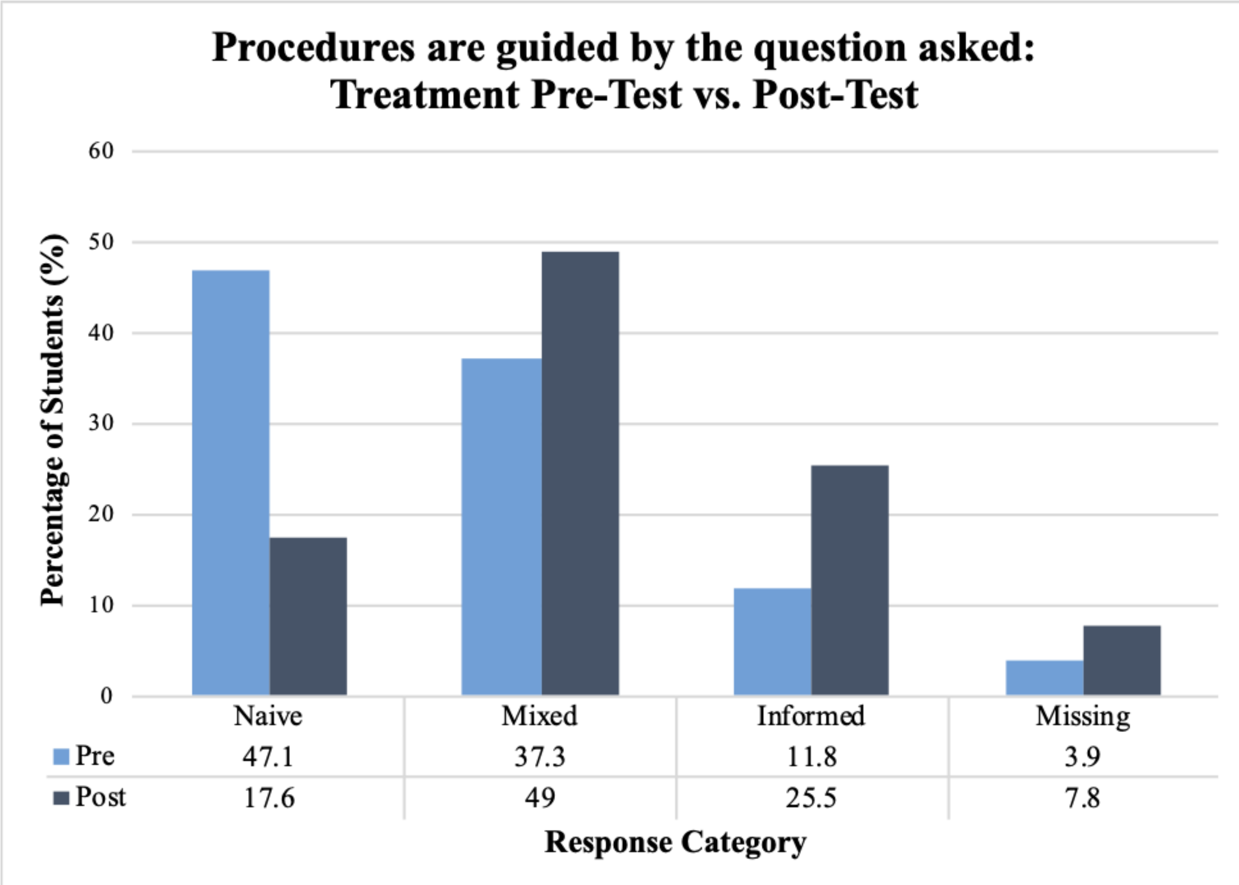


Figure 32. *Percentage of treatment group students' pretests versus posttests for each response category for NOSI aspect procedures are guided by the question asked.*

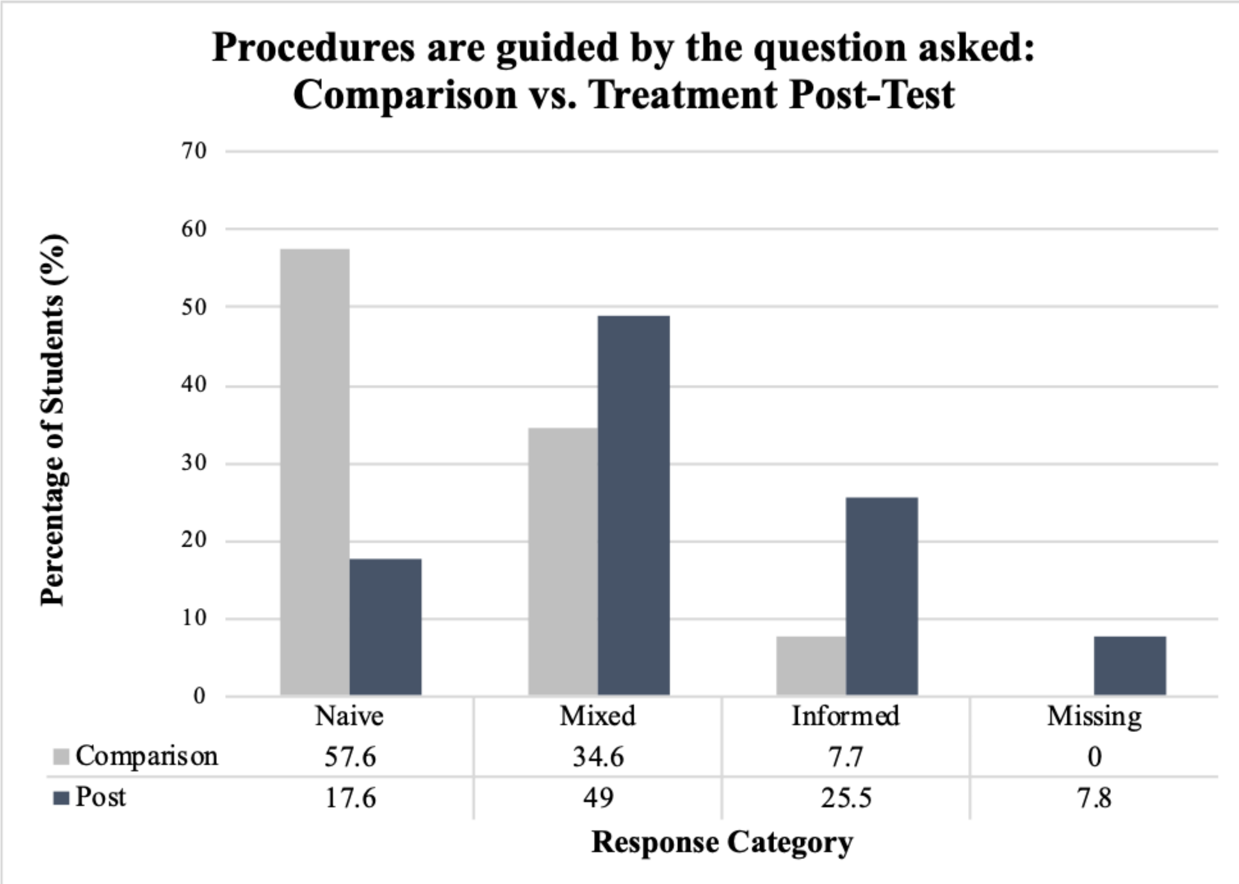


Figure 33. *Percentage of comparison group versus treatment group students' posttests for each response category for NOSI aspect procedures are guided by the question asked.*

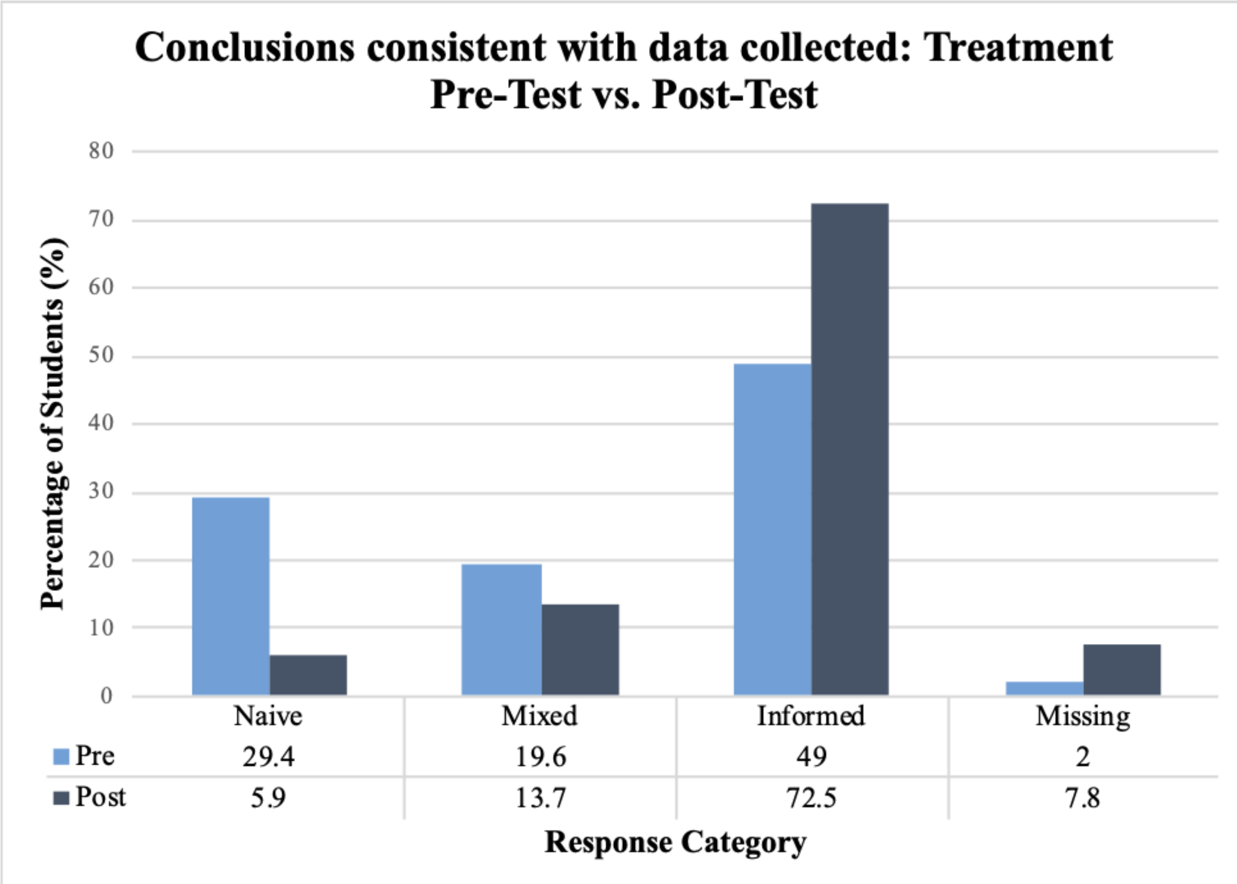


Figure 34. *Percentage of treatment group students' pretests versus posttests for each response category for NOSI aspect conclusions consistent with data collected.*

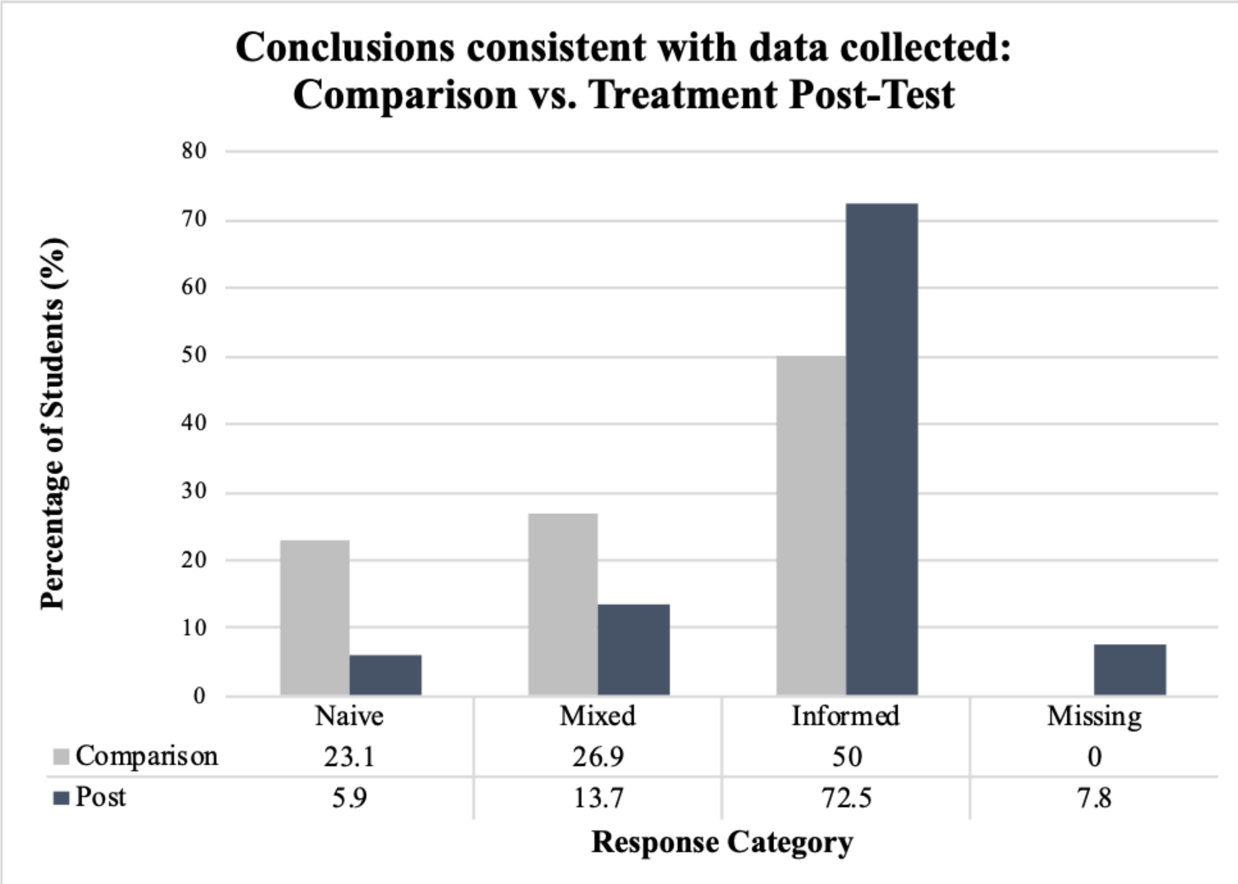


Figure 35. *Percentage of comparison group versus treatment group students' posttests for each response category for NOSI aspect conclusions consistent with data collected.*

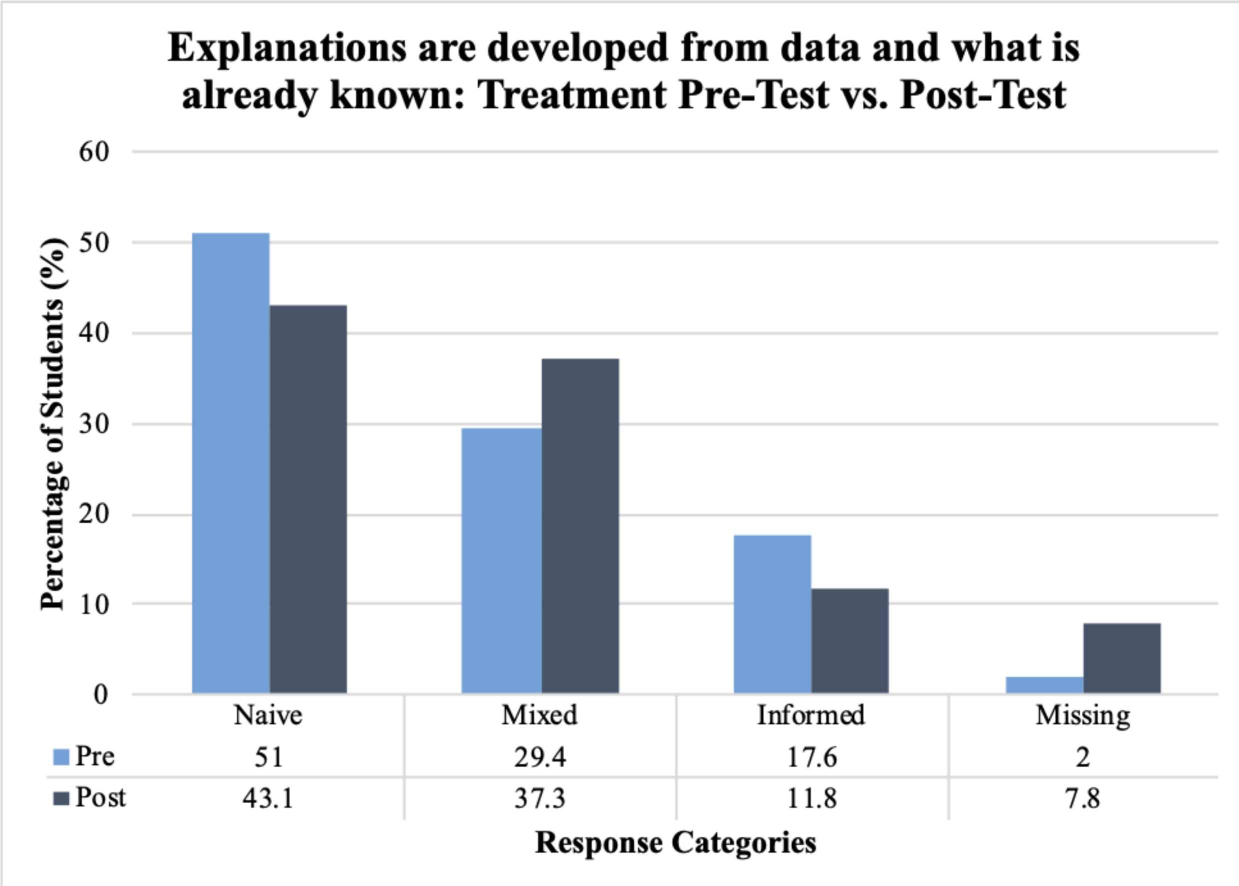


Figure 36. *Percentage of treatment group students' pretests versus posttests for each response category for NOSI aspect explanations are developed from data and what is already known.*

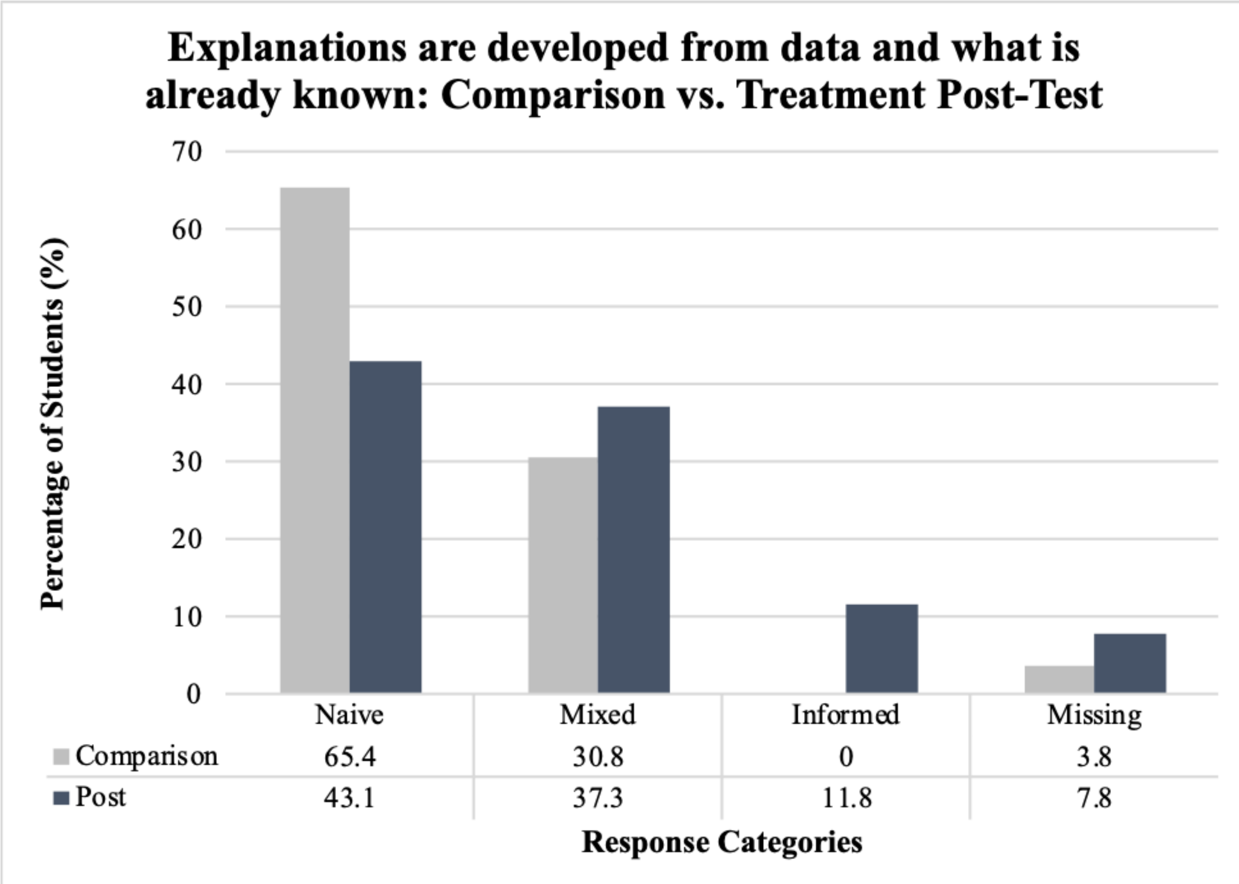


Figure 37. *Percentage of comparison group versus treatment group students' posttests for each response category for NOSI aspect explanations are developed from data and what is already known.*

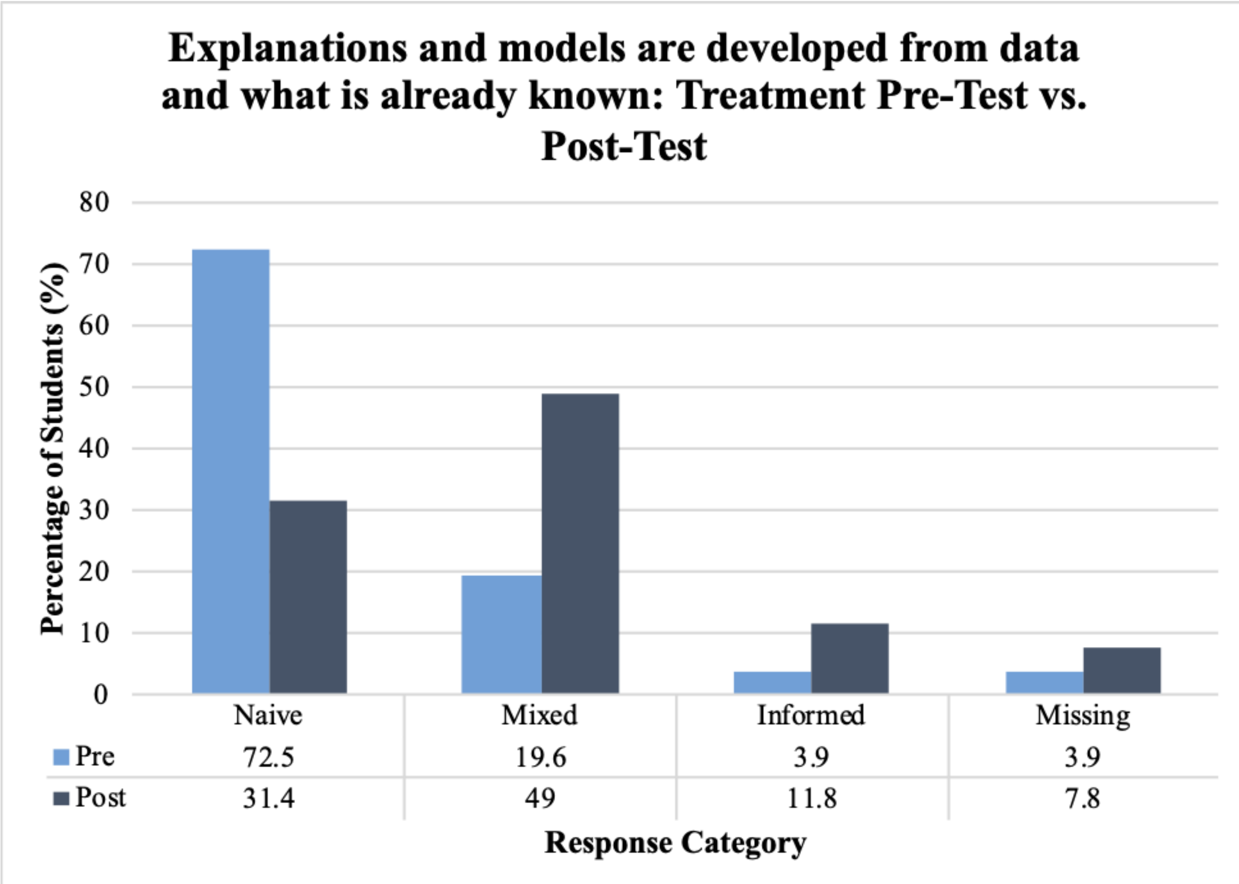


Figure 38. *Percentage of treatment group students' pretests versus posttests for each response category for NOSI aspect explanations and models are developed from data and what is already known.*

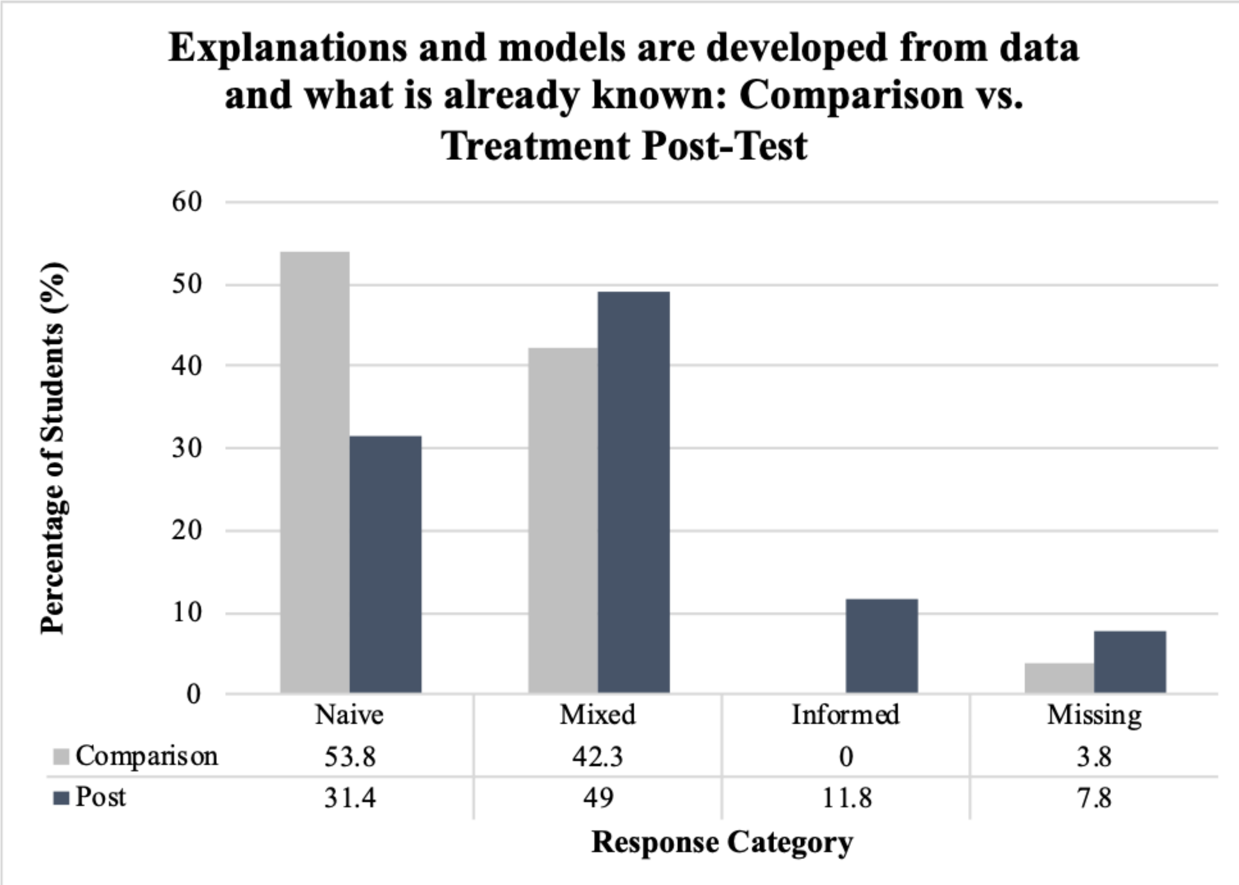


Figure 39. *Percentage of comparison group versus treatment group students' posttests for each response category for NOSI aspect explanations and models are developed from data and what is already known.*

Table 15. *Frequency of Treatment Group Students Categorized as Holding Naive, Mixed, and Informed Views across Eight Aspects of SI.*

		Naive		Mixed		Informed		Missing	
Aspects of Scientific Inquiry	VASI Item #	T Pre	T Post	T Pre	T Post	T Pre	T Post	T Pre	T Post
1. Scientific investigations all begin with a question but do not necessarily test a hypothesis.	2	9	8	30	23	10	16	2	4
2. There is no single set and sequence of steps followed in all scientific investigations (i.e., there is no single scientific method)	1a, 1b, 1c	30	18	18	19	2	10	1	4
3. Inquiry procedures are guided by the question asked; questions drive the process	5	24	9	19	25	6	13	2	4
4. All scientists performing the same procedures may not get the same conclusions	3a	34	22	10	14	6	11	1	4
5. Inquiry procedures can influence the conclusions	3b	16	13	24	25	9	9	2	4
6. Research conclusions must be consistent with the data collected	6	15	13	10	7	25	37	1	4
7. Scientific data are not the same as scientific evidence	4	32	15	13	15	5	17	1	4
8. Explanations and models are developed from a combination of collected data and what is already known	7a, 7b	26	22	15	19	9	47	1	4
8. Explanations and models are devel-	8a, 8b	37	16	10	25	2	6	2	4

oped from a combination of collected data and what is already known									

Table 16. *Frequency of Treatment Group Students Posttests and Comparison Group Students Posttests Categorized as Holding Naive, Mixed, and Informed Views across Eight Aspects of SI.*

		Naive		Mixed		Informed		Missing	
Aspects of Scientific inquiry	VASI Item #	TP	CP	TP	CP	TP	CP	TP	CP
1. Scientific investigations all begin with a question but do not necessarily test a hypothesis.	2	8	20	23	4	16	2	4	0
2. There is no single set and sequence of steps followed in all scientific investigations (i.e., there is no single scientific method)	1a, 1b, 1c	18	17	19	8	10	1	4	0
3. Inquiry procedures are guided by the question asked; questions drive the process	5	9	14	25	9	13	2	4	0
4. All scientists performing the same procedures may not get the same conclusions	3a	22	18	14	4	11	4	4	0
5. Inquiry procedures can influence the conclusions	3b	13	12	25	10	9	1	4	3
6. Research conclusions must be consistent with the data collected	6	3	6	7	7	37	13	4	0
7. Scientific data are not the same as scientific evidence	4	15	15	15	8	17	13	4	0
8. Explanations and models are developed from a combination of collected data and what is already known	7a, 7b	22	17	19	8	6	0	4	1
8. Explanations and models are developed	8a, 8b	16	14	25	11	6	0	4	1

from a combination of collected data and what is already known									

Appendix H: Student responses to the VASI

Examples of Comparison Group Students' Post Answers Representing Naive, Mixed, and Informed Views in the VASI Questionnaire.

Table 17. *Examples of Treatment Group Students' Pre-Intervention Answers Representing Naive, Mixed, and Informed Views in the VASI Questionnaire.*

SI Aspect	VASI Question	Naive	Mixed	Informed
There is no single set and sequence of steps followed in all scientific investigations (i.e., there is no single scientific method)	1a, 1b, 1c	*"Yes, because he had a guess that maybe the shape of the bird's beak was related to the type of food. Yes, because anything can be an experiment if there is a data to collect or something to test. Yes, one investigation is fossils, one person digs up the fossils and the other analyses it and puts it together."* *"Yes, because the person is trying to figure out the physical composure of a bird's beak. Yes because he has to see different birds that have the same beak to see if they eat the same thing. No, because you have to follow the scientific method. You need to find the problem, make a hypothesis, make a prototype, then experiment, after that you need to collect data, and share your data."*	*"Yes, because he finds information. No because the man was observing the birds not testing them. Yes, there are other ways because people do the same projects but using different methods."* *"Yes, if you're collecting data that is scientific. No because he is not testing anything. Yes, you can figure out different ways to do the same thing."*	*"Yes, because scientists study nature. No because experiments are things that can be tested. Yes, two ways to experiment and to observe and record the results of both."* *"Yes, I do consider this investigation to be scientific. I think because a short and hard beak can crack nut and shells. Long beaked are for picking up insects. No, I don't consider this an experiment because they aren't testing anything. Two investigations that follow different methods is when someone tests something to see if it's right or if someone observes something."*
Scientific investigations all begin with a question but do not necessarily test a hypothesis.	2	*"No, because not all investigations start with a question."* *"I think yes because to me a scientific method can't start without a random idea."*	*"Yes, because the only way the investigation can be created is by asking a question."* *"Yes, it always starts with a question."*	*"I agree with the student that said yes because you need to know the problem that you are trying to solve or experiment."* *"Yes, because the question is basically a topic. If there is no question you won't know what to gather info on."*
All scientists performing the same procedures may not get the same conclusions	3a	*"I think no because one person can do something wrong while the others can have correct answers/conclusions."* *"No because one of them can make a mistake and do the wrong things."*	*"No, because they can come up with different conclusions because one person could be more scientific than the others in the group."* *"No, they will not come up with the same conclusion. But if they did everything similar their data should be similar."*	*"They'll be different because not every person thinks the same all the time."* *"No, because they don't all think the same way."*
Inquiry procedures can influence the conclusions	3b	*"Yes, they will get the same data."* *"No, because if one step gets messed up it's going to end up impacting the whole project."*	*"No, because there is more than one way to solve a problem so there could be different results."* *"No, because they do different things and get something different."*	*"They will not. They will probably come up with solutions that are almost the same. Like scientists all ask how to cure cancer but they use different steps."* *"No, because their method of doing things can be different. Which will make their conclusion different."*

Scientific data are not the same as scientific evidence	4	*"No, because they both mean the same thing."* *"Yes, they are the same because data and evidence is information about a topic."*	*"Yes, because evidence is to prove something. Data is the recordings or results."* *"Data and evidence are not the same because data is like your information and evidence is the proof."*	*"Data and evidence are not the same because data is like your information and evidence is the proof."* *"Data is a set of information that is gathered. Evidence is information used to prove something."*
Inquiry procedures are guided by the question asked, questions drive the process	5	*"Team B because tests how a tire would react to a different surfaces of road."* *"Team B is better because you would want to buy a tire that can go on various types of roads because some people like to travel and there might be different types of roads."*	*"Team A because most roads are the same and you need to see which tire is the best so most likely you need to find what tire is the strongest not what road is the smoothest."* *"Team A is the best because the road is just one surface it doesn't have lots of surface in it so when they test many tires they find the one that adapts to that surface."*	*"Team A because their procedures go with the question they are trying to figure out.* *"Team A is better because the question asked about tires. And the question is dealing with tires not different roads."*
Research conclusions must be consistent with the data collected	6	*"A because it is getting left out in the sun."* *"A 'because with less sunlight can't grow as tall."*	*"B, I agree because the plant grow tall."* *"C, because it is not compatible with answers A or B because 10min =15cm, 15min=5cm, 20min= 10cm. It doesn't grow related to amount of sunlight."*	*"B, the graph says with 0 light the plant grew 25cm."* *"B, because the plant grew 25cm with no sunlight on the chart."*
Explanations and models are developed from a combination of collected data and what is already known	7a, 7b	*"Yes, because it can take big steps and it also is not going to fall over. Because they can run faster and take big steps."* *"I think scientists agree because it makes sense. The big bones on bottom and small bones on top. I think scientist can use tapes or making hypothesis or use the internet."*	*"Figure 1 is correct because it has big legs to holds its weight; while, in Figure 2 it has small legs. They use information of how other figures look like, so they could apply it to the figure."* *"Figure 1 looks like a T-Rex. Figure 2 will look like an overgrown amphibian or iguana. Looks and shape and information from the past."*	*"The dino(saur) would be able to move around easily because it has big legs compared to Figure 2. It would be hard for it to catch food so it would die quickly. They can use some research from other scientists and they can also look at animals that are alive today and look similar."* *"One reason is that the dinosaur will have a longer stride. Another is that if it was really Figure 2 it would fall over. Scientists can classify this dinosaur because of its shape and size of its bones."*
Explanations and models are developed from a combination of collected data and what is already known	8	*"A way or example of something that scientist are studying. Scientists use scientific models to classify and study specimens or objects. A globe is a model of the earth."* *"Basically like a 3D version of their thinking. They use it to experiment and basically show case their ideas. A bridge made of popsicle sticks."*	*"A scientific model helps you understand what you are working on. To see how something works. using candy as different types of soil layers."* *"Something that represents the procedure of your scientific process. To show what the outcome of experiment is. A model of bridge."*	*"A systematic description of an object or phenomenon that shared important characteristics with the object. Scientists use models to basically mirror what their experiment is. A solar system model."* *"A model/picture or figure of what the scientist is going to design. Most the time when they are doing an engineering and design project. A blueprint."*

Table 18. *Examples of Treatment Group Students' Post-Intervention Answers Representing Naive, Mixed, and Informed Views in the VASI Questionnaire.*

SI Aspect	VASI Question	Naive	Mixed	Informed
There is no single set and sequence of steps followed in all scientific investigations (i.e., there is no single scientific method)	1a, 1b, 1c	*"Yes, because he collected data and made a hypothesis and asked questions about the data he collected. Yes, it is an experiment because as said he collected data, made a hypothesis, and then he asked questions about the data. Yes, it can because people could make up their own ways to collect and analyze data."* *"Yes, because he got data from the birds. And he tested their beaks and feet. Yes, because he first tested out his first plan but then it probably didn't work so then he got data about the beaks. Yes, because one method is he can test their beaks and two the way they eat."*	*"This person's investigation is scientific. He is studying animals and investigating how birds are similar and different to other kinds. No because he is not testing anything. He is not looking/investigating how similar and different and other kinds of birds. Yes, because to investigate you need to examine all of the details. You can observe all the details and information by writing down data."* *"Yes, because he described the qualitative data of different kind of birds. No, because he wasn't testing anything. He was making an observation. Yes, on my science fair project I experimented which juice helps plants grow faster, apple or orange. I used different juices and orange grew faster."*	*"Yes, because he observed the birds just using his 5 senses. Observation uses the five senses for scientific investigations. This is not an experiment because this person isn't testing anything. Two investigations are observations and experiments. Observation means to observe, but experiment means to test it out."* *"Yes, because he has a question, he finds data, and the data he collects answers his question. No, he did not test anything. Yes, you can do experiments or observations."*
Scientific investigations all begin with a question but do not necessarily test a hypothesis.	2	*"Yes, because if there wasn't a scientific question, why would we do a scientific investigation."* *"No not always because someone could be making a scientific observation investigation."*	*"Yes, because the scientific question will lead you off."* *"Yes, because if there is no question being asked there is nothing to prove out data or to look up."*	*"Yes, because with a guiding question you will know how to start off your investigation."* *"Yes, you need a question because you need a reason for your investigation. Can't be out of the blue. The question guides what you're doing."*
All scientists performing the same procedures may not get the same conclusions	3a	*"Yes, because they will have the same answer to the questions."* *"No, they might have different data or take different measurements."*	*"No, because people can do the same procedure and come up with different conclusions and answers."* *"No, scientists will get different conclusions and will not have the same answer even though they did the same things."*	*"I cannot say for sure because some may have the same conclusions while others might have different conclusions because we think differently."* *"They might but not always. They might think differently."*
Inquiry procedures can influence the conclusions	3b	*"No, because someone is doing a different procedure."* *"No, because they are using different procedures. One person might add more of one material to their experiment than another person."*	*"Yes and no, because even though they followed different procedures they can still come up with the same conclusions. But they might not."* *"They will not come to the same conclusions because scientist follow their own procedures."*	*"They can. For example with Ms. Carrion we were trying to find which soil absorbs the most water. All the groups had the same question but different procedures, but we got the same conclusions."* *"They can get the same conclusions still. It is like math, 2+2=4 or 3+1=4"*
Scientific data are not the same as scientific evidence	4	*"They are different because data is what you did and you graph it, evidence is the details."* *"Data is when you collect stuff like if you're doing a project. Evidence is stuff you find to solve a case."*	*"Data are facts you collect. Evidence comes from the data."* *"Yes, data is collected facts. Evidence is facts based on data."*	*"They are different because evidence is data that is analyzed/interpreted and that is true. The data is information that can be true or not true, but people can do experiments to see if they're correct on their response."* *"Data is information that you collected from your experiment. Evidence is analyzed and interpreted data from your experiment."*
Inquiry proce-	5	*"Team B is better because they will get*	*"Team A is better because that one road*	*"Team A, their procedures were the best*

dures are guided by the question asked, questions drive the process		*a better answer."* *"Team B has better procedures because roads aren't all one texture."*	*surface could be the main road that tires usually become flat on."* *"Team A, because they test the tires on one type of road surfaces."*	*because their guiding question wasn't 'Do certain types of roads make tires more flat'? Team B did not follow the guiding question."* *"Team A is better because the question is on the brand of tires, and they tested different brands on one road. If it asked types of roads it would be B."*
Research conclusions must be consistent with the data collected	6	*"A, because to plants the sun is food and with more food they grow fast and healthy because the sun is the energy source."* *"A, because a plant grows healthier and taller with more sunlight."*	*"C, because the tallest plant grew with no sunlight therefore it is unrelated."* *"B, that is because the more sunlight they have the less time they have to use before sunlight to help grow. Because of more sunlight it could dry up the plant."*	*"B, because in the chart 25min of sunlight results in no growth at all, but 0 min of light resulted in the highest growth."* *"B, in the table, the less lights the taller the plants."*
Explanations and models are developed from a combination of collected data and what is already known	7a, 7b	*"Usually dinosaurs have small arms because that's basic information, and in Figure 2 the dinosaurs feet don't reach the ground. The particular dinosaur looks like a T-rex, and a T-Rex has small arms and huge legs and so does Figure 1."* *"Figure 1 makes more sense because when you look up pictures of dino(saur)s, you don't see the bigger part in the front. Plus, it would be harder for it to walk. Scientists use their resources like the internet."*	*"Reason 1- the second figure would not be able to hold itself up because arms are the legs. Reason 2 - the first figure looks more like a dinosaur than Figure 2. The way the model looks in Figure 2 can tell the scientists that its wrong."* *"I think because Figure 1 looks like it was never hunched over so it looks healthy. Then the legs are not bent and pointed left or right like in Figure 2. They can use research, and they can experiment with small types of dinosaurs like lizards and small dragons."*	*"Figure 1 has the best sorting over Figure 2 because the small hands are the legs it would not be balanced. Scientists use data and evidence because looking at our body the bigger part is at the bottom of our body."* *"No dinosaur has short legs and big arms, but they do have small arms and big legs OR both arms and legs are the same size. They can use data from the people before us."*
Explanations and models are developed from a combination of collected data and what is already known	8	*"A scientific model is a model. They study and ask questions and the procedure. An animal cell or plant cell."* *"Something that was an experiment. They use it before they do their question. My scientific model we made was our garden drawing."*	*"A model helps scientists gather data. To conduct an experiment, make a hypothesis, gather information from it, ask a question, observe and record results. Our indoor small plants."* *"A model that describes something dealing with science. They create the model to understand what they are working on more. solar system model project."*	*"A 3 or 2D figure used to show or explain something. Scientists use models to show or explain something or to show how something will look like or be. A soil layer model. "* *"Something that shows an event, object, or process. They make models of objects and use observations or experiments to collect data from the model. Water cycle diagram."*

Table 19. *Examples of Comparison Group Students' Post Answers Representing Naive, Mixed, and Informed Views in the VASI Questionnaire.*

SI Aspect	VASI Question	Naive	Mixed	Informed
There is no single set and sequence of steps followed in all scientific investigations (i.e., there is no single scientific method)	1a, 1b, 1c	*"Yes, I say this this investigation talks about the similarities and difference between the birds and what they eat. Yes, I consider this investigation to be an experiment because you can see what happens if a bird with a shirt beak eats soft shelled nuts instead of hard shelled. Yes, two methods can be if birds can soft or hard shelled."* *"Yes, because he made a hypothesis. Yes, because he used different types of*	*"Yes, because you observed and made a hypothesis. Also they used the scientific method. No, because you are not testing anything. You are observing. No because all you can so is observe and investigate. You can't run tests or anything else."* *"Yes, because this person has to go through the scientific method to answer. Yes, this is an experiment because the investigation can be proven wrong.*	*"Yes, and I think this is scientific because it explains how similar and different they are, and slim beaks don't have to be strong to eat insects, but strong small beaks have to be strong to eat shells. No because you're not really testing the bird or trying scientific things on it. You're just investigating it. Yes, because you have a method in which you look at it and follow but then you also can take the bird with you and*

		birds that eat the same types of foods and tested them to see their beaks. One investigation that follows a different method is replicate another one is to change an independent variable."	*Yes, it can because you can perform the experiment and observe for this investigation."*	*experiment on it."* *"Yes because he is talking about life science and the way they eat. No because all he has to do is watch different birds. Yes because they can experiment or investigate. They could watch the birds or they can experiment on them."*
Scientific investigations all begin with a question but do not necessarily test a hypothesis.	2	*"I agree with the student that says "no". Because any random question can be answered with the scientific method for example: do birds' beaks look similar to the type of food they eat."* *"I agree with the first student because a scientific question is the base of an experiment."*	*"Yes because you have to know what you're asking."* *"I agree with the student who says "yes" because you always ask questions when you do an investigation. Start with an hypothesis."*	*"I would agree with the student that says yes because if there's no question you don't know what you're searching for."* *"I agree with the one who says yes because in scientific investigations you always need a question so you can investigate and find the answer."*
All scientists performing the same procedures may not get the same conclusions	3a	*"Yes because there is no difference in what they did."* *"They will come to the same conclusions because they did the same procedures and the same questions."*	*"This would be natural, sometimes if both scientist think the same thing they would usually come up with the same answer but not always."* *"Not necessarily, they might because they are doing the same process. Then again, they may do the same process, but come up with different conclusions."*	*"No, because everyone does the same steps but think differently. Like 5 people might toast their bread however it depends how you toast it and how it cooks. It really depends on how people think."* *"No because one can think different at the end."*
Inquiry procedures can influence the conclusions	3b	*"They will most likely not come to the same conclusion, but one of them can always miscalculate."* *"No because they have different procedures."*	*"They will not because different procedures will come to different solutions."* *"Yes because you can get a solution more than one way."*	*"The scientist may come up with the same conclusion using different procedures because different procedures could lead to the same conclusion. They might do the procedures in a different order."*
Scientific data are not the same as scientific evidence	4	*"Data is to analyze. Evidence is to think of the answer."* *"Data is something you know, evidence is how you know."*	*"Data and evidence are two different words. Evidence is the work you show to people to prove a statement. Data is work you collect to answer a question."* *"Yes because data is what you collect and evidence is what you find about the data."*	*"Yes because data is where you collect information and evidence is where you have proof on how/where you find the answer."* *"They are different because evidence is a process that helps you prove something, and data is what you have collected."*
Inquiry procedures are guided by the question asked, questions drive the process	5	*"Team B because their test tires on different surfaces. But truly I say neither is better they are the same in different ways."* *"Team B, because when you test more subjects you are closer to getting to an answer."*	*"Team's A procedure is better than team B's procedure because they tested the tires to test which tires are best."* *"Team A, is better because they are comparing the tire to see which is better."*	*"Team A because they tested various tires' performance on one type of road surface."* *"Team A's procedure is better because they are testing more than one brand of tire."*
Research conclusions must be consistent with the data collected	6	*"A, sunlight is energy and soil."* *"A, because it grows."*	*"C, I chose C because the plants grew with or without sunlight."* *"B, because the plant grew more inches than the less sunlight."*	*"B, because if you look at 0 minutes of sunlight, its growth height is at 25cm but if you look at 25min in the sun, its height is at 0cm."* *"B, because the chart is 0 light = 25 growth and 5 light = 20 growth less lights the taller the plants."*
Explanations and models are developed from	7a, 7b	*"The dinosaur looks correct. They could've researched what the dinosaur should look like.*	*"Figure 1 has greater posture, but Figure 2 is a slouch. They measure the skeleton and weigh*	*No informed responses.*

a combination of collected data and what is already known		*Data and Hypotheses."* *"1. The arms are in the wrong place. 2. The legs are in the wrong place. Movies. Internet. Encyclopedia. TV Shows."*	*it."* *"A T-Rex has short arms and big legs. It's also never so far down. They use research and dig up fossils to predict what they look like."*	
Explanations and models are developed from a combination of collected data and what is already known	8	*"A model shows scientific evidence. To determine the answer to a question. A graph about something."* *"Model that is scientific. They use it to help with science. Baking soda in vinegar."*	*"A representation of something particular in the world. To figure out a specific problem going on in the world. A simulation"* *"A diagram of an object to show its physical presentation for more specific details. To get deeper specific details about an object. Solar system model"*	*No informed responses.*