EXAMINING THE INFLUENCE OF LESSON STUDY ON ELEMENTARY SCIENCE TEACHERS' PRACTICES

By

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A Dissertation Submitted in Partial Fulfillment
of the Requirements for the Degree of
Doctor of Philosophy in
Mathematics and Science Education

Middle Tennessee State University
May 2020

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ACKNOWLEDGEMENTS

I would like to first thank my husband, Devan, for pushing me to finish to the end. There were several times when I wanted to just give up, but he continually pushed me to press on to the finish line. I would like to also thank my “village.” These are the people who believed I could even when I did not. Thank you to Mimi Thomas for her mentorship and encouragement. Thank you to the BG-MSE. This group of like-minded individuals was formed and served to anchor me as I finished the journey. Thank you, Angela, Jessica, Andrea, Fonya, Lisa, and Vee for the encouragement and the constant reminder of the importance of not giving up because of those coming behind me.

Thank you to my Committee for remaining committed to this process until the end. Thank you to my co-chairs Dr. Cindi Smith-Walters and Dr. Angela T. Barlow for their leadership and commitment to seeing me accomplish this goal. A special thanks to Dr. Barlow who from the beginning went above and beyond to see this through to completion in a spirit of excellence that is unparalleled. Thank you for all of the PDF documents with the corrections long after you were no longer with us. Thank you to Dr. Lischka, for support in data analysis and just being an encourager and listening ear. Thank you to Dr. Bleiler-Baxter, Dr. Strayer, and Dr. Kaplan for support as well.

ABSTRACT

In the U.S., typical elementary science instruction has not supported young children engaging in sophisticated scientific practice or developing deep understanding of appropriate science concepts. This is inconsistent with the reform efforts set forth by *A Framework for K-12 Science Education* and the original mandates of the National Science Education Standards. Effective professional development can support teachers as they endeavor to meet the demands of the reform efforts. To this end, the purpose of this study was to examine the potential that the engagement in the lesson study process may foster in supporting the professional development of elementary science teachers. Using an embedded case study design, this study explored science teaching practices as the participants collaboratively planned and taught a science lesson. This study sought to determine: How does instructional practice within a science research lesson of a lesson study cycle compare to the typical instructional practices of fourth-grade teachers in science?

Both the Teaching Dimensions Observation Protocol and the Inquiry Continuum were used to analyze teaching practices both individually and holistically. The results of this study revealed the value of lesson study For supporting teachers in sampling inquiry-based instructional practices instead of the teacher-centered approach to science teaching displayed in individual classrooms. Results of individual analyses prior to engaging in lesson study revealed teacher-centered instructional practices being employed in each participant's science lesson. As a group engaging in lesson study, participants planned and implemented a more student-centered inquiry science lesson compared to individual instructional practices observed prior to lesson study. The motivation behind the inquiry-

focused instructional decisions made by the group was unclear but may be attributed to the assistance of the knowledgeable other. Future research with specific emphasis on the impact of the knowledgeable other would be of value to the research community. This study revealed the potential for lesson study to be a viable means of professional development to promote improved elementary science instruction and can inform professional development stakeholders as science education reform continues to progress.

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CHAPTER ONE: INTRODUCTION

Introduction

This study explored elementary teachers' instructional practices in science teaching as they participated in a lesson study. The study specifically compared typical instructional practices of the participants to instructional practices observed in the research lesson. Included in this chapter are the background and purpose of the study, its significance, key term definitions, and chapter summary.

Science Education in the U.S.

Historically, U.S. students have scored below their peers from other industrialized countries in science (Martin, Mullis, & Foy, 2008; Martin, Mullis, Foy, & Hooper, 2016; Organization for Economic Cooperation and Development [OECD], 2008, 2010; Provasnik, Malley, Stephens, Landeros, Perkins, & Tang, 2016). This claim is supported by a number of surveys on science education, including the 2005 National Assessment of Educational Progress (NAEP), the 2003 Trends in International Mathematics and Science Study (TIMSS), and the 2000 National Survey of Science and Mathematics (Roth & Given, 2008; Telese, 2008; Weiss, Pasley, Smith, Banilower, & Heck, 2003). The National Survey of Science and Mathematics, as well as the TIMSS Video Study, revealed a teacher-centered instructional focus in U.S. science classrooms. Although research supports using student-centered approaches to teach, the National Survey of Science and Mathematics reported that one-third of instructional time in K-12 classrooms was spent in class lecture and/or discussion, whereas one-sixth of the instructional time was spent on students reading textbooks and/or completing worksheets. Lecture-style instruction, also known as the teacher-centered approach to instruction, was a key component of science instruction, with 30% of the instructional time being devoted to lecture, according to the TIMSS 2003 International Science Report (Banilower, Smith, Weiss, Malzahn, Campbell, & Weis, 2013; Martin et al., 2004; Martin et al., 2016). These statistics contradict the use of student-centered science instruction supported by research.

In fact, effective science instruction is characterized by student interaction with the content (Banilower, Cohen, Pasley, & Weiss, 2010). Studies have shown that student interaction with science content in U.S. elementary classrooms is limited at best (Roth & Givvin, 2008; Weiss et al., 2003). This fact is supported by statistics from the 2003 NAEP (Banilower et al., 2013; Telese, 2008), which demonstrated a lack of student interaction with science content. Such a finding indicates that in a large percentage of science instruction, students predominately read from textbooks, with lesser amounts of time spent on hands-on activities. A more recent 2012 NAEP report (National Center for Education Statistics [NCES], 2012) showed growth in the amount of interactions students are having with hands-on activities and investigations in classrooms; however, the achievement gaps show no growth in underserved populations. In general, limited interactions with science content hinder effective science instruction (Banilower et al., 2010).

The TIMSS (Martin et al., 2004), as well as the 2006 Program for International Student Assessment (PISA) (OECD, 2008, 2010; Provasnik et al., 2016), shared the results of studies comparing science instruction in the U.S. to that of other countries. The TIMSS Video Study compared U.S. instructional practices in science and mathematics to four other countries with higher levels of science achievement. The science portion of the

TIMSS Video Study revealed two major differences between the U.S. and higher achieving countries. First, each of the higher achieving countries had an observable and distinct pattern of science teaching. Although the four countries did not share a common science teaching approach, each had a core instructional strategy for organizing science content. In contrast, the U.S. lessons were characterized by a variety of teaching approaches rather than one distinct way of teaching science. Second, although each country had its own approach, all of the higher achieving countries engaged students with core scientific concepts and ideas. In other words, the science lessons focused on content. In the U.S., however, content played a less-than-central role (and sometimes no role at all) in classroom instruction. Instead, U.S. lessons focused on engaging students in a variety of activities (Roth et al., 2006). In a more recent NAEP report from 2015, the data indicated that there has been some improvement in science achievement, but the U.S. has yet to outperform countries with similar achievement levels (Martin et al., 2016). As a result, reform in U.S. science instruction is greatly needed.

Science Education Reform

The results of these national surveys have not gone unnoticed. Significant strides have been made and continue to improve science education in the U.S. (American Association for the Advancement of Science [AAAS], 1990; NGSS Lead States, 2013; National Research Council [NRC], 1996; National Science Teachers Association, 2018). Organizations such as the NRC, National Science Foundation (NSF), and AAAS have committed both time and resources to improvement efforts (AAAS, 1990; Schweingruber, Keller, & Quinn, 2012). Achieve also led the charge in reforming National Science Standards with the development of Next Generation Science Standards

[NGSS] (NGSS Lead States, 2013). These organizations have sought to increase science, technology, engineering, and mathematics (STEM) achievement by improving scientific literacy for all students and preparing them for STEM careers (AAAS, 1993; Schweingruber et al., 2012).

In 1993, AAAS, who was working to increase STEM achievement in the U.S., started an initiative called Project 2061. The resulting publication was known as *Science for all Americans*. It has since been revised and renamed as the *Benchmarks for Science Literacy* (AAAS, 1993). One of the fundamental premises underlying Project 2061 curriculum reform included the promotion of literacy in science, mathematics, and technology. Also, of major importance was the notion that curriculum reform should be shaped by a vision of lasting knowledge and skills that all students should acquire prior to completing high school. AAAS (1993) further stated that reform must be comprehensive and long-term if it is to be significant and lasting.

The NRC also assisted in science education reform efforts and launched an effort for science education reform in 1996, resulting in the creation of the National Science Education Standards. One of the goals of these Standards included scientific literacy for all students. According to the NRC (1996), four major markers can be used to characterize the accomplishment of this goal. First, students should be able to experience the richness and excitement associated with knowing about and understanding the natural world. Second, they must use appropriate scientific processes and principles in making personal decisions. Third, students must be able to engage intelligently in public discourse about matters of scientific and technological concern. Finally, increased economic productivity through the use of knowledge, understanding, and skills is a goal of scientific literacy for all (NRC, 1996).

In the latest effort in science education reform, the NRC, AAAS, and Achieve, along with the NSTA, collaborated to create the NGSS (NGSS Lead States, 2013). The NRC was responsible for the first step of this process through the development of *A Framework for K-12 Science Education* (Schweingruber et al., 2012). This framework identified the types of science that all K-12 students must know; moreover, it was designed to overcome the weaknesses associated with previous science education standards. These deficiencies included a lack of systematic organization across multiple school years, an emphasis on discrete facts (with a focus on breadth over depth), and failure to provide students with engaging opportunities to experience how science is actually conducted (NRC, 2011). The second step of the process was managed by Achieve, in which a group of states collaborated to lead the development of K-12 science standards. This collaboration also included other stakeholders, both in higher education and industry. Following multiple reviews by an advisory committee and many other stakeholders, the NGSS were ready for adoption by individual states (NGSS Lead States, 2013).

Status of Elementary Science Instruction in the U.S.

In the U.S., typical elementary science instruction does not support young children engaging in sophisticated scientific practices or developing a deep understanding of appropriate science concepts (Trygstad, Smith, Banilower, & Nelson, 2013; Weiss et al., 2003). Activities that run smoothly and yield the desired results are often the focus of science instructional practice in elementary classrooms, as opposed to engaging students in meaningful, inquiry-oriented science teaching and learning (Appleton, 2002). Other researchers found that reform-based science instruction rarely takes place in elementary classrooms (Blank, 2013; Carlone, Haun-Frank, & Kimmel, 2010). Although elementary teachers are conscientious about the types of chosen activities, these activities often do not encompass the scope of best practices in science instruction.

In anticipation of the NGSS, the NSF-funded National Survey of Science and Mathematics Education was administered in 2012 by Horizon Research Incorporated. This survey provided an overview regarding the status of elementary science education in the U.S. This work revealed the need to adjust science teaching in elementary classrooms. Example indications included inconsistent teacher beliefs about what good science teaching involves, as well as the amount of time needed for science teaching in an elementary setting (Trygstad et al., 2013). The statistics presented in this survey confirmed the need for national reform in science, with specific attention given to elementary science and the role played by teachers in this reform.

The Role of Teachers

Teachers are the most important element of student education (Committee on Science and Math Teacher Preparation, 2001). As a result, the importance of the teacher's role in student achievement has been the focus of reform, in addition to changes in curricular materials. Consistent with the National Science Education Standards (NRC, 1996), the NSTA developed the *Standards for Science Teacher Preparation* (NSTA, 2003), which specifically addressed expectations for elementary science teachers. Three major expectations were listed as recommendations for these teachers: (1) teachers need to be prepared to teach science with a strong emphasis on observation and the description of events, manipulative objects, and systems, as well as identifying patterns in nature; (2) teachers should be prepared to effectively engage students in concrete manipulative activities that lead to the development of desired concepts through investigation and an analysis of experiments; and (3) teachers must be prepared to lead students to understand the unifying concepts of science, such as the nature of science, evolution, and the interrelationship between living and nonliving systems (NSTA, 2002).

Another NSTA standard for teaching science focused on teacher content competency. It was recommended that teachers of science in elementary grades demonstrate competency in three major scientific disciplines: life science, earth science, and space science (NSTA, 2006). Despite this recommendation, only one-third of K-5 teachers have had coursework in all three disciplines, and only another third has had coursework in two out of the three disciplines. Furthermore, 5% of teachers have had no coursework in any of the three disciplines (Trygstad et al., 2013). Such limited coursework for teachers has led to limited content preparedness (NSTA, 2006). In the National Survey of Science and Mathematics, teachers reported feeling unprepared to teach at least one of the three disciplines recommended by NSTA (Trygstad et al., 2013). The aforementioned recommendations are clearly aimed at preparing teachers to implement the vision of science reform instruction in U.S. elementary classrooms. Professional development (PD) can serve as a means to achieve this vision.

The Need for Professional Development

In order for science instructional practices to improve, increased opportunities are needed for teachers to engage in ongoing learning experiences (Darling-Hammond & McLaughlin, 1995). Such opportunities for ongoing PD serve to deepen teachers' content knowledge and assist in applying what they are learning in the classroom. PD programs serve as an effective means of facilitating change in the classroom (Banilower et al., 2010); moreover, it provides opportunities for teachers to continuously reflect on current practice, as well as construct new ways of understanding content, pedagogy, and learners (Darling-Hammond & McLaughlin, 1995).

Results from the National Survey of Science and Mathematics Educators supported the need for elementary science teachers to engage in more science-focused PD. Of the teachers surveyed, only half had participated in science-focused teacher training in the past three years. In addition, 15% of the teachers surveyed reported never having participated in a science-focused PD. When questioned about the total time spent on PD for science teaching, 60% of teachers reported that they spent less than six hours in science-related PD within the previous three years (Trygstad et al., 2013). Such brief exposure to a few hours of PD over several years most likely is insufficient in meaningfully enhancing teachers' knowledge and skills (Trygstad et al., 2013).

Lesson Study as a Model for Professional Development

One of the highest achieving countries cited by the 1999 TIMSS Video Study (Roth et al., 2006) and the more recent TIMSS report (Martin et al., 2016) in comparison to the U.S. was Japan. The TIMSS Study showed a marked difference in the Japanese approach to science instruction, compared to the other countries in the study. Japan demonstrated steady improvement in their instructional practice for elementary science education. In some respects, this improvement has been credited to a PD model known as lesson study (Lewis, Perry, & Hurd, 2004). The Japanese terms *jugyou*, which means instruction, lesson(s), and *kenkyuu,* which means research or study, are translated into lesson study. Taken together, *jugyou kenyuu* encompasses a group of instructional practices aimed at improving student achievement, as well as teaching. These practices include observation of a live classroom lesson by a group of teachers who gather data on the lesson and later collaboratively analyze the data (Lewis & Tsuchida, 1997). Lesson study has gained momentum in the U.S. as a viable means of PD for mathematics teachers (Lewis, 2016; Lewis, Perry, & Hurd, 2009; Perry & Lewis, 2009); however, its potential for supporting U.S. science teachers has not been well documented.

Purpose of Study

The purpose of this study was to examine the potential of the lesson study process in supporting elementary science teachers' PD. Specifically, by exploring teaching practices as the participants collaboratively planned and taught science lessons, this study sought to address the following question: How does instructional practice enacted within a science research lesson of a lesson study cycle compare to the typical instructional practices of fourth-grade teachers in science?

Significance of the Study

This study intended to contribute to the body of research in science education in two primary ways. First, this study contributed to the literature focusing on instructional practices for teaching science at the elementary level, with an emphasis on in-service versus preservice teachers. Next, this study added to the literature focusing on the use of lesson study in U.S. classrooms as a means for improving teacher instructional practice and, in turn, student achievement, particularly in science.

Definition of Key Terms

For the purpose of this study, the following terms are defined. These definitions will govern the use of the terms throughout this work.

Professional Development

In this study, the term *professional development (PD)* is defined as any activity in which a teacher engages to gain or increase knowledge through access to education and training opportunities. The purpose of such development is to improve professional practice.

Lesson Study

Lesson study is a type of PD that originated in Japan that allows teachers to scrutinize and improve instructional practice. Further, it allows teachers to look inductively at their current practice and work through an iterative process to improve that practice, thereby improving student achievement (Lewis et al., 2004).

Lesson Study Cycle

A *lesson study cycle* is defined as an iterative process in which teachers (1) engage in collaborative goal setting for student learning; (2) plan a research lesson that attempts to obtain these goals; (3) conduct the lesson with one teacher teaching the lesson, while the others observe and collect data; (4) reflect on and discuss the evidence obtained from the research lesson, utilizing it to improve the lesson; and, (5) if desired, reteach the lesson using a different teacher in a different classroom (Lewis, 2000).

Situated Learning

Anderson, Reder, and Simon (1996) described *situated learning* as a construct based on four major premises. First, learning is grounded in the actions of everyday situations. Second, knowledge is acquired situationally and transfers only to similar situations. Third, learning is the result of a social process encompassing ways of thinking, perceiving, problem-solving, and interacting, in addition to declarative and procedural knowledge. Last, learning exists in robust, complex social environments.

Reform-oriented Teaching Practices

Reform-oriented teaching practices are defined by Piburn and Sawada (2000) as extending beyond the classroom and centering on the development of critical thinking. Moreover, these practices move away from didactic, teacher-centered instruction and toward instruction that is constructivist in nature. This definition of reform expects students to use data to justify their opinions, experience ambiguity as a result of learning, and learn collaboratively from one another. This definition also presupposes that teachers will not emphasize lecture, but rather will stress a problem-solving approach and foster active learning.

Inquiry Continuum

The *Inquiry Continuum* was developed by the NRC (2000) in *Inquiry and the National Education Standards*. The continuum is based on the five essential features of inquiry as outlined in the above-mentioned document and organized by variations of each feature, ranging from more to less learner self-direction or less to more teacher direction.

Summary of Chapter

This chapter provided background information on the following areas: (1) science education in the U.S.; (2) science education reform; (3) the status of elementary science education in the U.S.; (4) the role that teachers play in reform; (5) the need for professional development; and (6) the use of lesson study as a professional development model. This chapter also outlined the purpose and significance of the study, as well as definitions of the key terms. In the next chapter, an introduction of the study and its theoretical and conceptual frameworks are presented. Additionally, lesson study research is reviewed, along with research on instructional change as a result of effective professional development.

CHAPTER TWO: LITERATURE REVIEW

Introduction

In the U.S., typical elementary science instruction has traditionally fallen short in helping young children engage in sophisticated scientific practice or develop a deep understanding of appropriate science concepts (Banilower et al., 2013; Trygstad et al., 2013; Weiss et al., 2003). Studies in the U.S. have shown that student interaction with science content is limited at best (Roth & Givvin, 2008; Weiss et al., 2001). This finding is inconsistent with current reform efforts set forth in *A Framework for K-12 Science Education* (NRC, 2011), as well as the original mandates of the National Science Education Standards (NRC, 1996), which encouraged innovative methods of teaching. These concerns pointed to the importance of the teacher's role in student achievement. Teacher effectiveness has been the focus of reform, in addition to changes in curricular materials (NRC, 2011; NSTA, 2006). Effective professional development can support teachers as they prepare to meet the demands of reform efforts (Desimone, Porter, Garet, Yoon, & Birman, 2002). Therefore, the purpose of this study was to examine the potential of the lesson study process in supporting the professional development of elementary science teachers.

This chapter reviews the relevant literature for the purpose of providing the theoretical and conceptual background for this study. First, instructional practices for science in elementary classrooms are discussed. This section is followed by a description of effective professional development for teaching science, with an emphasis on elementary school. Next, the origin and use of lesson study as a means of professional development are presented. Finally, the theoretical and conceptual frameworks provide a description of (1) how students learn science; (2) the concept of teacher learning through situated learning; and (3) an introduction to the Inquiry Continuum (NRC, 2000) for evaluating science teaching practices.

Instructional Practice

This section provides an overview involving the status of science education in elementary schools. Included in this description are the roles and responsibilities of teachers to teach a reform-oriented, inquiry-based science curriculum, as recommended by the National Science Education Standards (NRC, 1996) and *A Framework for K-12 Science Education* (NRC, 2011).

In a report on K-8 science, *Taking Science to School*, the National Academy of Science emphasized the fundamental importance of engaging children in the knowledge-building practices of science (Duschl, Schweingruber, & Shouse, 2007). Typical elementary science instruction does not support young children in terms of engaging in sophisticated scientific practice or developing a deep understanding of appropriate science concepts (Banilower et al., 2013; Trygstad et al., 2013; Weiss et al., 2003).

Instead, Appleton (2002) found that teachers used five common criteria to determine which activities should be used in their science curriculum. First, elementary teachers utilized hands-on activities. Second, teachers sought out interesting and motivating activities for children. Third, they trended toward activities with a clear outcome or result and activities that were manageable in the classroom. Fourth, their choice of activities was guided by the use of readily available equipment. Last, it was important for teachers to have classroom activities that could integrate science into the themes. These activities, however, limit science instructional practices in elementary classrooms by focusing on activities that run smoothly and yield the desired result, as opposed to engaging in meaningful, inquiry-oriented science teaching and learning (Appleton, 2002). Although several of the aforementioned criteria are supported by the principles of effective science teaching (NRC, 2011), authentic science teaching goes far beyond choosing the best activity.

In 2012, Horizon Research Incorporated administered the NSSME (Trygstad et al., 2013). This survey provided an overview regarding the status of elementary science education in the U.S. The first indicator of importance revealed by the survey was that teachers' beliefs were inconsistent with what research defines as effective science teaching. In effective science instruction, special emphasis is placed on understanding the nature of scientific knowledge (Weiss et al., 2001). Forty percent of elementary teachers agreed that instructors should explain an idea to students before having them consider the evidence for that idea.

This finding is inconsistent with one of the National Science Education Standards' recommendations for effective science teaching, which states that students should be able to support scientific claims with evidence (NRC, 1996; Weiss et al., 2001). Half of the teachers reported that hands-on activities and labs should be used to reinforce ideas that students have already learned; in addition, more than 80% believed that students should be given new vocabulary definitions at the start of a new lesson. Effective science teaching draws on students' past experiences and elicits their prior knowledge (NRC, 1996; Weiss et al., 2001). Another indicator of the importance placed on science instruction in elementary classrooms was the amount of time dedicated to teaching science. The survey showed that in grades K-5, only 18-23 minutes per day were devoted to science instruction, as compared to 85 to 90 minutes in reading and language arts, and 52 to 61 minutes in mathematics (Trygstad et al., 2013). Research by Blank (2012) indicated that students receiving more than three hours per week of science instruction scored better on the fourth-grade science NAEP assessment than students who received less than one hour per week in science instruction. The NSTA has advocated for increased time in the science curriculum as a key factor in improving science education and student outcomes, particularly in elementary education (NSTA, 2002, 2018).

More recently, the Horizon Research Institute released its report on the 2018 National Survey of Science and Mathematics Education (NSSME+) (Banilower et al., 2018). The authors of this report also surveyed more than 7,000 teachers across the country on both their beliefs about science teaching as well as their instructional practices. At least 90% of the teachers surveyed believed in reform-oriented teaching practices, which included the following ideas: (1) teachers should ask students to support their conclusions with scientific evidence; (2) students learn science best by doing science; (3) students learn best when science instruction is connected to their everyday lives; and (4) most science classes should allow students the opportunity to apply scientific ideas to the real world. Although a large percentage of teachers ascribed to reform-oriented practices, many continued to hold to traditional methods of science instruction. Despite research that suggests otherwise (NRC, 2005), roughly one-third of teachers surveyed at each grade level believed that science teachers should explain science ideas to students before having them consider the evidence for that idea. Additionally, more than half believed that laboratory activities should be used to reinforce science content previously learned by students.

The 2018 NSSME+ also reported data on instructional activities and the amount of time devoted to science instruction in elementary science classrooms, compared to mathematics. In grades four through six, 35% of teachers reported teaching science all or most days every week of the school year (Banilower et al., 2018). In the 2018 survey, the average number of minutes dedicated to science instruction increased to an average of 27 minutes per day, from 18-23 minutes in the 2012 survey (Banilower et al., 2018; Weiss et al., 2001). Teachers also reported the types of activities that students were engaged in during science instruction. Forty-eight percent of the science teachers surveyed reported that they explain scientific ideas to the whole class; 55% engage in whole class discussion; 30% have students work in small groups; 16% have students engage in hands-on experiences; and 20% focus on literacy skills, utilizing information texts and reading and writing skills (Banilower et al., 2018). Although some reform-oriented practices are present, traditional methods and strategies continue to be used.

These statistics point to the need for specific attention to elementary science reform and a shift toward more effective science teaching, as recommended by the National Standards for Science Teaching. The NSTA (2018) recently released a position statement that described the essential features of a high-quality elementary science education. Four key principals to guide elementary science education were identified. These included: (a) the key role of the elementary learning environment to the learning of science; (b) the capacity of elementary learners to engage in sophisticated scientific and engineering practices to develop a conceptual understanding over time; (c) the engagement of elementary students in the broader community of science; and (d) adequate time every school day to engage elementary students in high-quality science instruction that involves them in the process of doing science (NSTA, 2018).

Also included in this position statement were 13 recommendations that directly related to instructional practice in the elementary science classroom. These recommendations were closely aligned to the NRC (1996) National Science Education Standards, particularly Standard B, which focused on the guidance and facilitation of student learning in elementary science in five ways. These included the following: (a) focusing inquiries while interacting with students; (b) orchestrating discourse among students about scientific ideas; (c) challenging students to accept responsibility for their own learning; (d) recognizing and responding to student diversity and encouraging all students to participate fully in science learning; and (e) encouraging and modeling skills of scientific inquiry, as well as curiosity, openness to new ideas, and data and skepticism. The biggest difference between the two sets of recommendations is the emphasis placed on engaging students in authentic inquiry instruction using the three dimensions outlined by *A Framework for K12 Science Instruction*. The table below (Table 1) shows the alignment between the foundational NRC (1996) document compared to the most recent NSTA position statement. These recommendations provide educators with a framework to support the development of a solid foundation in science for elementary students in the classroom.

Table 1

Alignment of NSTA recommendations for effective elementary science teaching to the National Science Education Standards

National Science Education Standards (NRC, 1996)	NSTA Position Statement (NSTA, 2018)
Focusing inquiries while interacting with students	• allow students time and space for sense-making through experimental design; • embed authentic mathematical applications within scientific investigations • work to integrate all disciplines in the elementary curriculum with science
Orchestrating discourse among students about scientific ideas	• explicitly integrate a variety of discussions and lessons that build an understanding of the Nature of Science; • involve students in scientific discourse leading to evidence-based conclusions that can be communicated effectively through speaking and writing; • immerse students in a variety of scientific text and literature genres that enable them to develop and understand the different purposes of each;
Challenging students to accept responsibility for their own learning	• provide authentic summative and formative assessments; allow students to work collaboratively in which knowledge is based on empirical evidence;

(continued)

National Science Education Standards (NRC, 1996)	NSTA Position Statement (NSTA, 2018)
Recognizing and responding to student diversity and encouraging all students to participate fully in science learning	• consider the learners' individuality within their social and cultural contexts while exposing students to novel experiences that move toward more abstract concepts; • build on students' prior knowledge and confront previously embedded misconceptions • utilize equitable teaching practices by promoting science learning for all children, regardless of language, gender, race, ethnicity, age, skill, cognitive or physical ability
Encouraging and modeling skills of scientific inquiry, as well as the curiosity, openness to new ideas, and data and skepticism that characterize science	• engage students in three-dimensional instruction by teaching using science and engineering practices, embed those practices through cross-cutting concepts and use real-world interests and relevance • help students understand the difference between scientific data, beliefs, and opinions

Professional Development

A strong need exists for mechanisms by which teacher instructional practice is evaluated and improved (Trygstad et al., 2013). This need can be met by teacher exposure to sustained, high-quality professional development opportunities (Borko, 2011; Singer, Lotter, Feller, & Gates, 2011). This section will first provide a description of the current state of professional development, as well as the characteristics of effective professional development. Next, an overview of lesson study is provided, as well as the origin of lesson study in the U.S. Findings from empirical studies are presented, and finally, challenges associated with implementing lesson study in the U.S. are discussed.

Professional Development for Science Teachers

Prompted by the necessity to meet the need for student achievement in the face of standards reform, teachers have sought out and participated in various activities that provide opportunities for professional growth (Desimone et al., 2002). The availability of such professional growth opportunities has been varied and numerous. Despite the fact that teachers are able to locate and attend various types of professional developments, the resulting opportunities are often ineffective in creating change (Yoon, Duncan, Lee, Scarloss, & Shapeley, 2007). According to Darling-Hammond, Wei, Richardson, and Orphanos (2009), 90% of teachers reported participating in professional development; yet, a majority of these teachers also reported that the professional developments was inadequate.

The format of professional development offered to and attended by teachers is usually a one-time workshop (Gulamhussein, 2013). This type of workshop typically results in little change with respect to teacher practice and student achievement (Yoon et al., 2007). This lack of positive change in teaching or learning demonstrates the ineffectiveness of such an approach. Gulamhussein (2013) attributed the ineffectiveness of the one-time workshop model to a faulty assumption regarding teachers' knowledge of instructional practice. Creators of the one-time workshop model assumed that teachers' major challenge is a lack of knowledge in effective teaching practices. This assumption further follows that if the void in knowledge were filled, then teachers would be able to change (Gulamhussein, 2013). However, this model has proved to be insufficient in producing enduring change in teacher practice that can foster student achievement (Harwell, 2003). As a result, a great deal of research has focused on identifying the characteristics of effective professional development (e.g., Darling-Hammond & McLaughlin, 1995; Desimone, 2011; Garet, Porter, Desimone, Birman, & Yoon, 2001; Loucks-Horsley, Stiler, Mundry, & Love, 2010; Mundry, 2005; Supovitz & Turner, 2000).

Characteristics of Effective Professional Development

As recently as the late 1990s, the research has indicated that teacher professional development efforts were often criticized for their lack of continuity or ability to produce substantive change in teacher practice and student learning (Loucks-Horsley et al., 2010). This criticism has not gone unnoticed. Efforts to reform professional development (e.g., Desimone et al., 2002; Yoon et al., 2007), as well as attempts to characterize effective professional development (e.g., Desimone & Garet, 2015; Guskey, 2003; Loucks-Horsley et al., 2010; Mundry, 2005; Supovitz & Turner, 2000) have motivated much of the education research by various stakeholders (e.g., Darling-Hammond & McLaughlin, 1995; Desimone, 2011; Garet et al., 2001; Loucks-Horsley et al., 2010; Mundry, 2005; Supovitz & Turner, 2000). Reform efforts have brought about the need to define what elements constitute effective professional development. The desire for clearly defined characteristics emerged in the wake of new demands on teachers to improve student learning.

Guskey (2003) posited that researchers have struggled to come to a consensus about what characteristics constitute effective professional development. After examining 13 lists regarding the perceived characteristics of effective professional developments and supporting research, he concluded that there existed wide variation in these lists, and the resulting list of characteristics was often inconsistent and contradictory (Guskey, 2003). In spite of this notion, researchers continue to work at compiling a list of key characteristics concerning effective professional development in the face of education reform (e.g., Darling-Hammond & McLaughlin, 1995; Desimone, 2011; Desimone & Garet, 2015; Garet et al., 2001; Loucks-Horsley et al., 2010).

In contrast to the view presented by Guskey (2003), other researchers have reached consensus about which factors contribute to effective professional development (e.g., Darling-Hammond & McLaughlin, 1995; Desimone, 2011; Desimone & Garet, 2015; Garet et al., 2001; Loucks-Horsley et al., 2010; Mundry, 2005; Supovitz & Turner, 2000). From this consensus, six recurring characteristics of effective professional development emerged: (1) immersing teachers in inquiry, questioning, and experimentation; (2) intensive and sustained support; (3) engaging teachers in concrete teaching tasks that integrate teachers' experiences; (4) focusing on subject-matter knowledge and deepening teachers' content knowledge; (5) providing explicit connections between professional development activities and student outcome goals; and (6) providing connections to larger issues of education/school reform (Singer et al., 2011).

In addition to this list, Mundry (2005) cited a need for effective professional development to foster certain elements of collaboration. She posited that effective professional development experiences allow teachers to work with colleagues and other experts in a professional learning community; such experiences also support teacher leadership by allowing teachers to support other teachers, become agents of change, and promote reform (Mundry, 2005). The process of defining specific characteristics of effective professional development was a consequence of education reform efforts to promote teacher practice and student achievement. These efforts have yielded considerable benefits in the science classroom (Banilower et al., 2010; Supovitz & Turner, 2000).

In a more recent report, *Effective Teacher Professional Development*, Darling-Hammond, Hyler, and Gardner (2017) expounded upon Desimone's (2009) definition of effective professional development, which states that effective PD is content focused, contains opportunities for active learning, is collaborative and aligned to relevant curricula and policies, and provides sufficient learning time for participants. The report both confirmed and expanded upon the aforementioned description by stating that as structured professional learning, effective professional development results in changes to teacher knowledge and practice, and thus, improves student learning. It further noted that effective professional development is a product of both external and job-embedded activities that increase teachers' knowledge and help them change their instructional practices in ways that support student learning (Darling-Hammond et al., 2017).

In addition to a more refined definition of effective professional development, the report, (i.e., Effective Teacher Professional Development [Darling-Hammond et al., 2017]), offered seven key design elements for professional development to be considered in designing and implementing professional development for educators. These included: content-focused PD, the incorporation of active-learning strategies that utilize adult learning theory, collaborative support in a job-embedded context, using models and modeling effective practices, the provision of coaching and expert support, offering opportunities for feedback and reflection, and sustained duration (Darling-Hammond et al., 2017).

Professional Development as a Means of Improving Science Achievement

Quality professional development is of utmost importance in science education (Darling-Hammond et al., 2017). As a result, science education reformers have made strides in fostering improved teacher practice and student achievement through professional development (Supovitz & Turner, 2000). The NRC (1996) proposed standards for science teacher professional development. Moreover, the National Science Education Standards offered a clear strategy for developing teacher skills and professional knowledge within the standards for professional development for teachers of science using the following four focus areas: learning science content through inquiry; integrating knowledge about science with knowledge about learning, pedagogy, and students; developing an understanding of and ability to engage in lifelong learning; and maintaining coherence and integration within professional development programs. These four standards offered by the National Science Education Standards intersect with the characteristics offered for effective professional development. Table 2 shows the intersection between the professional development standards outlined by the National Science Education Standard to the most recent report on effective teacher professional development.

Table 2

Intersection of NSES Professional Development Standards to the Characteristics of Effective Science Professional Development

NSES Professional Development (NRC, 1996)	Effective Professional Development (Darling-Hammond et al., 2017)
Learning science content through inquiry	• Content-focused PD
Integrating knowledge about science with knowledge about learning, pedagogy, and students	• Incorporating active-learning strategies that utilize adult learning theory • Using models and modeling effective practices
Developing an understanding of and ability to engage in lifelong learning	• Offering opportunities for feedback and reflection • Sustained duration
Maintaining coherence and integration within professional development programs	• Collaborative support in a job-embedded context • Provision of coaching and expert support

In 2006, the NSTA released a position statement addressing professional development for science educators. Several principles were recommended by the NSTA, specifically for teachers of science and based on the current literature on professional development (e.g., Darling-Hammond & Sykes, 1999; Darling-Hammond et al., 2017; Loucks-Horsley et al., 2010). Some of these principles echoed the characteristics of effective professional development, while others were specific to teaching science in a classroom setting. The following principles apply directly to professional development for science educators. First, professional development needs should be based on both the learning needs of the students in understanding the difficult subject matter, as well as the needs of science educators in addressing student needs. Second, professional development should support the science teachers, both as individuals and as members of a collaborative group of educators. Next, professional development should concentrate on specific issues of science content and pedagogy that are derived from research and exemplary practice. Last, programs should connect issues of instruction and student learning to the actual classroom context (NSTA, 2006). The remaining principles for professional development proposed in the NSTA's position statement are closely aligned with the qualities of effective professional development as displayed in Table 3. The information described in this table demonstrates the alignment of the proposed principles with supporting research on effective professional development.

Table 3

Principles for Professional Development for Science Educators

Principle	Darling-Hammond & McLaughlin, 1995	Desimone, 2011	Garet et al., 2001	Loucks-Horsley et al., 2010	Mundry, 2005	Supovitz & Turner, 2000
Immersing teachers in inquiry, questioning, and experimentation	X			X		X
Intensive and sustained support						X
Engaging teachers in concrete teaching tasks that integrate teachers' experiences	X		X	X		X
Focusing on subject-matter knowledge and deepening teachers' content knowledge	X	X		X		X
Providing explicit connections between the professional development activities and student outcome goals	X		X	X		
Providing connections to larger issues of education /school reform	X	X	X	X		X
Foster and environment of collaboration among teachers	X		X		X	

In order to properly support teachers in implementing reformed-based practices, changes in professional development for science teachers must occur. According to *A Framework for K-12 Science Education* (NRC, 2011), professional development that includes science-specific induction and mentoring, and that is ongoing is needed to support in-service teachers' implementation of the framework. Further, professional development should be closely linked to classroom practices and needs, closely tied to standards, and specific to the school-, district-, or state-mandated curriculum (NRC, 2011). The type of professional development for preparing science teachers to effectively implement reform-oriented teaching practices echo the aforementioned principles for science teachers' professional development (NSTA, 2006) and the foundational National Science Education Standards for Professional Development for Teachers of Science (NRC, 1996).

Lesson Study

As a professional development tool, lesson study is a means for teachers to scrutinize and improve instructional practice. Further, it allows teachers to look inductively at their current practice and work through an iterative process to improve that practice, thereby improving student achievement (Huang, Li, & Zhang, 2011; Lewis et al., 2006). In the sections that follow, an overview of lesson study is offered, followed by the origin of lesson study in the U.S.

Overview of lesson study. Lesson study, also known as research lessons in Japan, is touted as the major means of professional development for teachers of mathematics and science in Japanese elementary and middle schools (Dubin, 2010). As such, Japanese educators credit lesson study as the key to instructional improvement individually, school-wide, and nationally (Lewis, 2000). Researchers of lesson study agree that the following components are characteristic of the lesson study process: collaborative planning by teachers; formulating long-term goals for student learning and development; planning a lesson based on meeting these goals; teaching the lesson in an actual classroom while others observe the lesson; observing student learning, engagement, and behavior; and discussing and revising the lesson. Lesson study in Japan takes on many forms and exists in different contexts, the most common of which being the within-school research lesson (Lewis, 2000; Lewis & Tsuchida, 1997; Murata & Takahashi, 2002; Rock & Wilson, 2005). Other types of research lessons include public lesson studies, which are open to teachers and policymakers from outside the school, and lesson studies that occur as a part of national conferences or teaching circles for the purpose of demonstration (Lewis, 2000).

The principles of lesson study naturally align with the characteristics of effective professional development as well as the standards for professional development geared toward science educators (see Table 4). Three key connections are noted here. First, the collaborative nature of lesson study allows teachers to work with their colleagues from the same school, grade, and/or department (Garet et al., 2001). Second, through research lessons, teachers are able to be actively involved in observing, analyzing, and applying feedback to teacher practice (NSTA, 2006). Third, lesson study follows a professional development model that is ongoing and allows teachers to align their lessons with state and local standards (Garet et al., 2001). These key features of lesson study point to the potential for its use in supporting U.S. teachers.

Table 4

Alignment of Lesson Study with the Principles of Professional Development (NSTA, 2006)

NSTA Principle	Lesson Study Alignment
Based on student learning needs	X
Based on the needs of science educators	
Engage science educators in transformative learning experiences	X
Integrated and coordinated with other initiatives in schools	X
Embedded in the curriculum, instruction, and assessment practices	X
Involve teachers in observing, analyzing, and applying feedback	X
Connect issues to the actual context of classrooms	X

Origin of the lesson study in the U.S. In response to data released from the 1995 TIMSS Video Study, Stigler and Hiebert (1999) authored the work, *The Teaching Gap: Best Ideas from the World's Teachers for Improving Education in the Classroom*, which examined mathematics teaching in three countries, including Japan. In the book, the authors highlighted the Japanese form of professional development, lesson study. The authors cited the research-based features of lesson study as being essential for teacher learning and improvement and as a leading factor in deciding to emphasize the practice of lesson study in their work (Stigler & Hiebert, 2009). Although lesson study was not the focus of their work, the authors introduced the idea in approving terms, as described below:

> We are attracted to the Japanese notion of lesson study because it lays out a model for teacher learning and a clear set of principles or hypotheses about how teachers learn. Lesson study embodies a set of concrete steps that teachers can take over time to improve teaching. These steps may need to be modified to work in the United States. But we believe it is better to start with an explicit model, even if it needs revising, than with no model at all. (Stigler & Hiebert, 1999, p. 150)

This work, coupled with actual videos from the TIMSS Study, helped education stakeholders realize how attractive this type of professional development is; moreover, this work sparked a rise in lesson study implementation in the U.S. (Chokshi & Fernandez, 2005).

Lesson study research in the U.S showed rapid growth, which was led by key researchers, practitioners, and organizations supporting professional development in mathematics classrooms (e.g., Huang et al., 2011; Lewis, 2000; Stigler & Hiebert, 2009). At the onset of lesson study in the late 1990s, Catherine Lewis and Makoto Yoshida conducted research in this area (Lewis, 2000; Lewis & Tsuchida, 1998; Yoshida, 1999). On the West Coast, Lewis led a project at Highlands Elementary School that supported teachers in lesson study within the California Bay area, with the help of a classroom teacher and a mathematics coach from an area school (Lewis & Tsuchida, 1998). During the 2000-2001 school year, teacher volunteers at Highlands Elementary School conducted two cycles of lesson study and presented their results to the faculty during the spring. This demonstration convinced a majority of the faculty to begin lesson study the following year. Lewis continued to monitor lesson study progress at Highlands Elementary School. She stated, “Research at this school provides an existence proof that U.S. teachers can use lesson study to improve instruction and a window into the conditions needed for its success” (Lewis, Perry, Hurd, & O’Connell, 2006, p. 273). The results of this study and similar studies in mathematics education found that lesson study helped to foster an improved quality of instruction as a result of the lesson study collaboration (i.e., Chokski & Fernandez, 2005; Prince, 2016).

Simultaneously on the East Coast, an NSF-funded project to start lesson study was led by Makoto Yoshida and Clea Fernandez in New Jersey. Through this project, teachers at Patterson School #2 in New Jersey (in conjunction with the Greenwich Japanese School in Connecticut) were able to learn how to plan, observe, and reflect on teaching through lesson study. The Japanese teachers served as mentors for the U.S. teachers throughout the project’s duration, helping to teach the U.S. instructors about the basic elements of the lesson study process and coaching them through planning and implementation (Fernandez, Cannon, & Chokski, 2003). The researchers noticed that there were several challenges to implementing Japanese lesson study in the U.S. classroom, but they were confident that lesson study held great potential for supporting U.S. teachers to engage in more reform-based teaching (Fernandez et al., 2003).

The focus of the aforementioned lesson studies was mathematics rather than science. Although lesson study played a pivotal role in science education reform in Japan, it has not had the same impact in the U.S. (Lewis, 2016). In the U.S., the majority of lesson study research has been focused on mathematics, with less attention given to the science classroom. Although limited, the practice of lesson study in science in the U.S.

spans all levels of education. Research on lesson study use for science has found a place in the realm of higher education. Specifically, lesson study has been used as a means of preparing preservice science educators (e.g., Carrier, 2011; Marble, 2007), as well as graduate teaching assistants (e.g., Dotger, 2011; Dotger et al., 2012; Lampley, 2015). Secondary and middle-school educators have also found utility in lesson study to improve science teaching (e.g., Ahearn, 2011; Anfara, Lenski, & Caskey, 2009; Mutch-Jones, Puttick, & Minner, 2012).

Research by Marble (2007) found that the use of lesson study helped to give teachers a critical lens with which to view instructional practice. Dotger et al. (2012) noted several benefits of lesson study with graduate assistants in her study. First, lesson study provided a framework for discussion of instructional topics and student ideas. Next, lesson study provided graduate assistants more influence over the lessons that they were responsible for teaching. Third, the study found that there was a change in the nature of conversation between the graduate assistants around science instruction. Finally, lesson study provided a space for graduate assistants to gain a more effective understanding of the teaching topics. Additionally, results from a study of middle school science and special educators engaged in lesson study revealed an increase in teachers' ability to set instructional context and adapt an instructional plan to meet the needs of all science students in an inclusive classroom. The results of these studies, although varied and limited, reveal the impact of lesson study in the U.S. Therefore, this dissertation sought to contribute to the body of literature on lesson study use in science education.

Theoretical Framework

The theoretical framework for this study draws from two major areas. First, the learning theory described in the National Research Council's (NRC) publication, *How Students Learn: Science in the Classroom,* (NRC, 2005), is addressed. Next, a discussion will follow with regard to teacher learning using situated learning theory (Lave & Wenger, 1991). These ideas are used to support the researcher's use of lesson study for the proposed study.

How Students Learn Science

In *How People Learn* (Donovan & Bransford, 2005), three major principles were highlighted as they pertain to teaching science. First, teachers must engage students' prior knowledge and recognize that new understanding is constructed on the foundation of one's existing understanding and experience. Students make sense of the natural world through their everyday experiences. Through these experiences, false conceptions of how the world works may be embedded and are sometimes difficult to dislodge. Second, teachers must understand the essential roles of factual knowledge and conceptual frameworks in understanding; acquiring factual knowledge is only useful within the context of a conceptual framework. Teachers must possess and be able to convey what it means to do science. *A Framework for K-12 Science Education* identifies seven scientific and engineering practices in which students should engage in the science classroom. These practices include: asking questions; developing and using models; planning and carrying out investigations; analyzing and interpreting data; constructing explanations; engaging in argument from evidence; and obtaining, evaluating, and communicating information (Krajcik & Merritt, 2012; NRC, 2011). Finally, teachers must understand and communicate with their students the importance of self-monitoring or metacognition, which involves an evaluation of one's own thinking. Together, these principles are intended to guide teachers' thoughts as they prepare to teach science. Moreover, these principles can be useful as teachers evaluate their own teaching practice.

The framework for learning set forth by the NRC (2005) in the aforementioned document consists of a classroom environment that is learner-centered, knowledge-centered, assessment-centered, and community-centered. The authors described a learner-centered environment as one in which ideas and understandings that students bring to the classroom are emphasized while the students engage in activities and discussions that draw out what or how they know. Alternatively, a knowledge-centered learning environment is characterized by the assurance that the necessary concepts and information are learned. An assessment-centered environment is characterized by a context in which students are helped to assess (1) the quality of their hypotheses or models; (2) the adequacy of their methods and conclusions; and (3) the effectiveness of their efforts as learners and collaborators. All of these are enveloped within a community-centered learning environment, in which dialogue and discussion are encouraged to help develop a culture of respect, inquiry, and risk taking (where it is acceptable to disagree). This framework supports effective science teaching, and for the purpose of this study, served as a lens through which to view teacher instructional practice, both before and during participation in lesson study.

Teacher Learning via Situated Learning Theory

According to Lave and Wenger (1991), learning is situated within an authentic activity, context, and culture. Anderson et al. (1996) described situated learning as based on four major premises, all of which are well supported by the use of lesson study. First, learning is grounded in the actions of everyday situations. Lesson study situates teachers in the classroom where they practice daily. Second, knowledge is acquired situationally and is transferred only to similar situations. Lesson study allows teachers to engage in the practice of teaching and apply what they have observed and learned in a research lesson environment to similar situations in their own classrooms. Third, learning is the result of a social process encompassing ways of thinking, perceiving, problem solving, and interacting, in addition to declarative and procedural knowledge. Lesson study allows teachers to be active members of a learning community in which they (1) interact with current ways of thinking and practice; (2) reflect on those practices; and (3) collaboratively adjust as the need arises. Finally, learning is not separated from the world of action, but rather exists in robust, complex, social environments made up of actors, actions, and situations. In other words, situated professional learning opportunities are not merely confined to the context of teachers' own classrooms (Borko, Koellner, Jacobs, & Seago, 2011). According to Ball and Cohen (1999), practice-based professional development entails identifying the central activities of instructional practice, selecting and creating materials that usefully depict the work of teaching, and using these materials to create teacher learning. Again, lesson study supports this premise by providing teachers with the opportunity to be engaged in a thriving learning community that promotes action in everyday situations.

Conceptual Framework

The National Research Council (2000) in *Inquiry and the National Science Standards* defined inquiry as:

> A multifaceted activity that involves making observation; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (p. 23)

Reformed-based science teaching goes beyond merely teaching science through inquiry; indeed, inquiry is one of many methods teachers might use to increase students' understanding of the natural world around them (NRC, 2000).

In the abovementioned document, five essential features of teaching science as inquiry were defined. These features were created based on the abilities necessary for students to engage in inquiry within the classroom context. These features include the following, in which the learner: (a) engages in scientifically oriented questions; (b) gives priority to evidence in responding to questions; (c) formulates explanations based on evidence; (d) connects explanations to scientific knowledge; and (e) communicates and justifies explanations (NRC, 2000). Teaching approaches, classroom activities, and materials should include all five of the essential features. Teachers have the ability to utilize each feature in ways that vary, based on the amount of student or teacher responsibility. For instance, all scientific inquiry should involve asking and answering questions; however, this might include questions posed by teachers or questions that are refined or posed by the student.

From the above-mentioned document, the Inquiry Continuum was created (NRC, 2000). The continuum is based on the five essential features of inquiry and includes variations of each of the essential features found in Figure 1. Each feature's variations range from more to less learner self-direction or from less to more teacher directions.

Essential Feature	Variations			
1. The learner is engaged in scientifically oriented questions.	The learner poses a question.	The learner selects among questions and poses a new question.	The learner sharpens or clarifies a question posed by the teacher, materials, or other sources.	The learner engages in questions provided by the teacher, materials, or other sources.
2. The learner gives priority to evidence in responding to questions.	The learner determines what constitutes evidence and collects it.	The learner is directed to collect certain data.	The learner is given data and is asked to analyze them.	The learner is given data and is told how to analyze them.
3. The learner formulates explanations from evidence.	The learner formulates an explanation after summarizing evidence.	The learner is guided in the process of formulating explanations from evidence.	The learner is given possible ways to use evidence to formulate an explanation.	The learner is provided with evidence.
4. The learner connects evidence to scientific knowledge.	The learner independently examines other resources and forms links to explanations.	The learner is directed toward areas and sources of scientific knowledge.	The learner is given possible connections.	
5. The learner communicates and justifies explanations.	The learner forms a reasonable and logical argument to communicate explanations.	The learner is coached in the development of communication.	The learner is provided with broad guidelines to sharpen communication.	The learner is given the steps and procedures for communication.
	More-----------Amount of Learner Self-Direction-----------Less Less--- Amount of Direction from Teacher or Material --- More			

Figure 1. Essential features of classroom inquiry, Inquiry Continuum (NRC, 2000, p. 29).

The essential features outlined in Figure 1 focus on learners and how they engage in inquiry in the science classroom, with varying degrees of teacher direction. How the teacher facilitates inquiry in the classroom is crucial to determining the extent to which students adequately engage in inquiry (NRC, 2000). Table 5 shows how the essential features align with the science practices from the *A K-12 Framework for Science Education* (NRC, 2011). In order to facilitate reform-oriented teaching in science classrooms, teachers must engage students in inquiry through science practices.

Table 5

Essential Features of Inquiry Overlapped with Science Practices

Essential Features (NRC, 2000)	Science Practices (NRC, 2011)
The learner is engaged in scientifically oriented questions.	1. Asking questions (for science) and defining problems (for engineering) 3. Planning and carrying out investigations
The learner gives priority to evidence in responding to questions.	4. Analyzing and interpreting data 6. Constructing explanations (for science) and designing solutions (for engineering)
The learner formulates explanations from evidence.	4. Analyzing and interpreting data 6. Constructing explanations (for science) and designing solutions (for engineering)
The learner connects evidence to scientific knowledge.	6. Constructing explanations (for science) and designing solutions (for engineering) 7. Engaging in argument for evidence
The learner communicates and justifies explanations.	7. Engaging in argument for evidence 8. Obtaining, evaluating, and communicating information

Chapter Summary

This chapter provided the guiding theoretical and conceptual frameworks of the study, along with a review of relevant literature describing instructional practice in elementary science education, characteristics of effective professional development, and the origin and use of lesson study in the U.S. The next chapter outlines the methodology used in this study, including a research overview, rationale, and context. The following chapter also includes a description of the participants, instruments and data sources, data analysis, and limitations and/or delimitations of the study.

CHAPTER THREE: METHODOLOGY

Introduction

U.S. students continue to underachieve in science and mathematics (Martin, Mullis, & Foy, 2008; Martin, Mullis, Foy, & Hooper, 2016; Organization for Economic Cooperation and Development [OECD], 2008, 2010; Provasnik, Malley, Stephens, Landeros, Perkins, & Tang, 2016). A key factor that contributes to student achievement is teacher practices (Committee on Science and Math Teacher Preparation, 2001). Research has shown that authentic professional development opportunities improve teaching practice, and thus, improve student achievement (Darling-Hammond et al., 2009). To this end, the current study aimed to describe the experiences of teachers engaged in an authentic professional development opportunity: lesson study.

The purpose of this study was to examine the potential of the lesson study process in supporting elementary science teachers' PD. Specifically, by exploring teaching practices as the participants collaboratively planned and taught science lessons, this study sought to address the following question: How does instructional practice enacted within a science research lesson of a lesson study cycle compare to the typical instructional practices of fourth-grade teachers in science?

This chapter begins with a research overview, which includes the rationale underpinning this study, as well as the research question, followed by a description of the research context and participants. Next, the instruments and data sources are described, followed by the study's procedures and data analysis techniques. Finally, the limitations, delimitations, and issues of trustworthiness of the study are described.

Research Overview

Creswell (2007) described qualitative research methodology as "the assumptions and use of interpretive and theoretical frameworks that inform the study of research problems addressing the meaning individuals or groups ascribe to a social or human problem" (p. 44). This process of research involves fielding emergent questions and procedures, collecting data typically within the participants' setting, and conducting a data analysis by inductively building from particulars to general themes. Given the intent of the study, a qualitative methodology was used to collect and analyze the data, specifically, the case study methodology. Those who engage in this form of inquiry support ways of examining research that honors an inductive style, a focus on individual meaning, and the importance of rendering a situation's complexity (Creswell, 2007).

For the purpose of exploring science teaching in elementary classrooms, the following research question was examined: How do instructional practices enacted within a lesson study cycle compare to the typical instructional practices of fourth-grade teachers in science?

Rationale for Case Study

Examining how participation in lesson study influences elementary teachers' instructional practices lends itself to the case study model of qualitative research. According to Stake (1995), case studies are a strategy of inquiry in which the researcher explores a program, event, activity, process, or one or more individuals in-depth. Cases are bounded by time and activity, and researchers collect detailed information using a variety of data collection procedures over a sustained time period. Yin (2003) stated that a case study design should be considered when:

> (a) the focus of the study is to answer "how" and "why" questions; (b) you cannot manipulate the behavior of those involved in the study; (c) you want to cover contextual conditions because you believe they are relevant to the phenomenon under study; or (d) the boundaries are not clear between the phenomenon and context. (p. 2)

The current study sought to answer the question of how instructional practices enacted within a lesson study cycle compare to typical instructional practices of fourth-grade science teachers. This study utilized a single descriptive case study with embedded cases. Moreover, the study's design was used to describe an intervention or phenomenon; in this case, the use of lesson study as a professional development model, and the real-life context in which it occurred (Yin, 2013). The single case consisted of a group of four fourth-grade teachers, with each teacher representing an embedded case.

Research Context

This study occurred in an elementary school located in a suburb of the capital city in the center of the state. At the time of the study the student body was composed of the following racial classifications: 93% white, 2% Hispanic, and 2% African-American. The remaining student population consisted of various other ethnic groups. Less than 5% of students were classified as having a disability, and less than 2% were classified as having limited English proficiency. The demographics of the faculty and staff were similar in terms of ethnic/racial origins.

Participants

The participants of this study were three fourth-grade teachers at Middleview Elementary School (Pseudonym). Each of the three participants served as the embedded cases (Yin, 2013. Each participant taught in self-contained classrooms, and science instruction was a part of the existing curriculum. A meeting was conducted between the researcher and the building administrators to discuss participant selection. The participants were carefully selected based on the needs of the researcher and the potential for the selected teachers' growth, as suggested by the school administrators. For this study, the researcher needed teachers in similar grade levels who taught a similar science curriculum. This group of teachers comprised the lesson study group. A brief description of each participant follows.

Samantha Adams (Pseudonym)

Samantha was a white female in her early twenties and a recent graduate of an education program at a local four-year university. The year in which this study was completed was the first year that she had ever taught, and she was placed in the fourth-grade team. She graduated with a B.S in Elementary Education.

Christina Thomas (Pseudonym)

Christina, a white female in her late thirties, had been teaching for four years in various grades within the elementary school. This was her second year of being a part of the fourth-grade team. She was pursuing a Specialist in Education degree in Curriculum and Instruction at the time of the study.

Hannah Kennedy (Pseudonym)

Hannah, also a white female in her late thirties, had a total of four years of teaching experience at the time of the study, all of which had been at the fourth-grade level. The highest degree that she obtained was a Master of Education in Curriculum and Instruction.

Instruments and Data Sources

Using multiple data sources adds to the richness of a qualitative study (Creswell, 2007). The researcher collected data in various forms, before and during the lesson study, to provide a means of data triangulation. These data sources included participant responses to writing prompts, demographic surveys, and transcripts of video and audio recordings of lessons, lesson study artifacts, and observation protocol notes. In the following sections, the data sources and instruments for this study are described.

Writing Prompt

The participants completed a writing prompt (see Appendix A), provided by the researcher, prior to participation in the lesson study. The purpose of the prompt was to inform the researcher of each participant's perspective of her own current classroom science teaching practices.

Teacher Demographic Survey

Participants were asked by the researcher to complete the Teacher Demographic Survey (see Appendix B) at the onset of the lesson study process via Google Forms. The survey was adapted from a demographic survey from the Online Education Resource Library Instrument database. The purpose of this survey was to gather demographic information, including years of teaching experience, grades taught, and college background, specifically in science. The survey also asked participants about previous PD experiences and prior preparation for teaching science.

Teaching Dimensions Observation Protocol

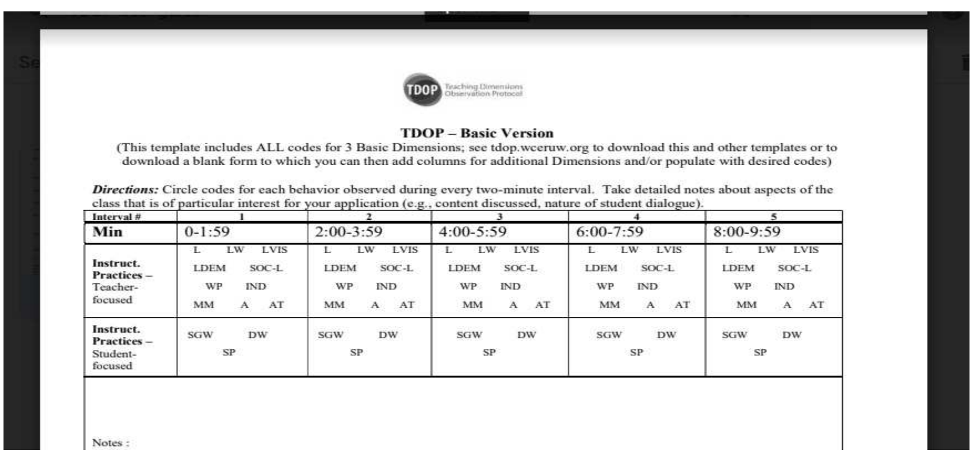
The Teaching Dimensions Observation Protocol (TDOP) (see Appendix C) is an instrument designed to provide users with rich descriptions of exactly what happens in the classroom (Hora & Ferrare, 2014). Moreover, the TDOP characterizes various facets of the learning environment, specifically on teaching practices. This protocol allows users to focus on the characteristics of the learning environment rather than judging the quality of instruction. Employing this instrument assisted the researcher in observing and documenting individual teacher practices as they taught science lessons.

The TDOP consists of three basic dimensions, including instructional practices or teaching methods, student-teacher dialogue, and the use of instructional technology. The instrument also contains three optional dimensions that include the potential for student cognitive engagement, student engagement or time-on-task, and pedagogical strategies. The TDOP includes predetermined codes that correspond to the sub-dimensions for each of the overarching dimensions. For example, the instructional practices or teaching methods dimension is subdivided into teacher- and student-focused instruction. The teacher-focused instruction sub-dimension includes codes such as lecture (L), lecture while writing (LW), and Socratic lecture (SOC-L). The student-focused instruction sub-dimension includes codes such as small group work/discussion (SGW), deskwork (DW), and student presentation (SP). The student-teacher dialogue dimension is subdivided into teacher- and student-led dialogue, each of which has its corresponding codes. A full list of the codes can be found in Appendix C.

Validity and reliability of the TDOP was predetermined by the creators of the instrument. Face-to-face construct validity for each of the codes and categories was tested through preliminary fieldwork and feedback from disciplinary and education experts. Inter-rated reliability (IRR) of the instrument was achieved through a rigorous training process that included in-depth discussion of individual codes as well as practice coding and team coding. IRR was calculated using Cohen's kappa scores (Hora, 2013).

The researcher utilized the online version of the instrument as a means of documenting the teachers' instructional practices, prior to and during the lesson study process. One of the features involving the online version of the instrument is its editable nature. The instrument in the online version provided the option to modify the codes based on the researcher's needs. For the purpose of this study (and in order to provide continuity in the data analysis), *a priori* codes were used to analyze the documents and videos provided by the participants.

Each teacher submitted a video of her current teaching practices, which were coded using the TDOP. The researcher assigned codes for two-minute intervals of the submitted video lessons and made notes (see Figure 2).



TDOP – Basic Version

(This template includes ALL codes for 3 Basic Dimensions; see tdop.wceruw.org to download this and other templates or to download a blank form to which you can then add columns for additional Dimensions and/or populate with desired codes)

Directions: Circle codes for each behavior observed during every two-minute interval. Take detailed notes about aspects of the class that is of particular interest for your application (e.g., content discussed, nature of student dialogue).

Interval #	1	2	3	4	5
Min	0-1:59	2:00-3:59	4:00-5:59	6:00-7:59	8:00-9:59
Instruct. Practices – Teacher-focused	L LW LVIS LDEM SOC-L WP IND MM A AT	L LW LVIS LDEM SOC-L WP IND MM A AT	L LW LVIS LDEM SOC-L WP IND MM A AT	L LW LVIS LDEM SOC-L WP IND MM A AT	L LW LVIS LDEM SOC-L WP IND MM A AT
Instruct. Practices – Student-focused	SGW DW SP	SGW DW SP	SGW DW SP	SGW DW SP	SGW DW SP

Notes :

Figure 2. Example of the TDOP two-minute interval data collection and coding.

Below is a sample of a two-minute interval of a transcript with its corresponding codes. The section of the transcript provides representative statements that were indicative of the assigned codes. Codes are located in parentheses at the end of the statements with which they correspond.

1-1 Hannah: All right, so today we are building on our Louisiana Project like we talked about before. I want everyone to direct their attention over here because this is going to be whole group at first, and then you will go back into your Louisiana groups and do some things with them that you will see connected here in a moment. So, who can tell me what you know about the word *system*? What is a system? (IDQ) (SL)

1-2 Student: Something that you do every day that repeats like a pattern. (SR)

1-3 Hannah: OK, so there is a pattern involved in the system.

1-4 Student: A system has steps. (SR)

1-5 Hannah: OK. A system has steps.

1-6 Student: It's basically like, you know how machines have systems? They follow what is meant to do. Say there is a system to (Pause) (SR)

1-7 Hannah: OK, so it follows a series of steps often. OK.

1-8 Student: (Inaudible)

1-9 Hannah: OK, so you're saying? What I hear you saying is that systems vary depending on the purpose. So, there's a system that has this set of boundaries and outcomes, and there's a system that would have a completely different set of boundaries? OK. Let's think about a system that we all know and love or hate. Let's talk about an aquarium. Is an aquarium a system? (ICQ)

1-10 Student: Yes.

1-11 Hannah: So, let's see if we can revise our definition based on some of these words that we have out here (Pointing to a list of terms on the board). So, we've already talked about a system just a little bit: We're going to come back to that. What are the boundaries of our system here? What would you say are the boundaries of our aquarium? (Students' hands are raised. Hannah calls on a student.) (IDQ)

1-12 Student: Umm, maybe the glass on the outside. (SR)

1-13 Hannah: OK, so, the glass on the outside. What else? (IDQ)

1-14 Student: Security guards on the outside that are like protecting people from like getting in. (SR)

1-15 Hannah: Well, we're talking about like a fish tank at home. I don't know about you, but mine does not have security guards, but if you're somewhere like Sea World, and there's a gigantic aquarium, that might be the case (Calls on another student).

1-16 Student: You have to learn how to filter.

1-17 Hannah: Is it a boundary? So, let's talk about the definition of a boundary. What is a boundary? (Calls on a student). What's a boundary? (IDQ)

1-18 Student: The boundary is like the outside. You have to stay inside the edge. (SR)

In the preceding sample transcript, the researcher attached codes to some lines of text. The first code that was attached was the Socratic lecture code. The description provided for the teachers' actions in the Socratic lecture (SL) is as follows: the instructor is talking to students while asking multiple successive questions to which students are responding. Students' responses are either guiding or being integrated into the discussion (TDOP code bank). The way that the students were seated around the teacher and the board, as well as the constant back-and-forth exchange between the teacher and the students, prompted the researcher to use this code. Instructor display questions (IDQ) and student response (SR) were the other two codes identified in this interval. The instructor posed questions in order to solicit a response from the students throughout this interval. No other question types were offered, and no questions were posed by the students. This section was provided to offer an example of the rationale for the codes utilized by the researcher.

Field Notes

The researcher collected fieldnotes (see Appendix E) during the teaching of the research lessons. This form of data collection served the purpose of making objective notes pertaining to the classroom environment, as well as observations of informal conversations between the participant teaching the research lesson and the students, along with conversations among the teachers who were observing the lesson. The fieldnotes contained as much detail as possible.

Audio Reflection

Following each interaction with the participants, the researcher recorded their audio reflections. These reflections were used to provide context for the notes that had been taken and to record the information that was obtained via informal conversations among the participants following the audio recorded sessions. The reflections were also transcribed.

Lesson Plan Template

Participants collaboratively planned a lesson during the second stage of the lesson study cycle. The lesson plan template was provided by the researcher and was used as a guide for the participants as they planned their research lesson (see Appendix F). The lesson plan template was created by the Lesson Study Group (Chokshi, Ertle, Fernandez, & Yoshida, 2001). The participants opted to use the lesson plans that they used regularly due to familiarity.

Video Recordings

Each of the participants submitted video recordings of the science lessons they conducted in their classrooms. The researcher evaluated these lessons using the TDOP to describe the observed teaching practices for each teacher and the Inquiry Continuum (NRC, 2000) to categorize those practices prior to participating in the lesson study. These lessons were used to describe the typical teaching practices in each classroom. The research lessons in the lesson study process were also video recorded and transcribed.

Audio Recordings

Audio recordings were taken and transcribed for key pieces of the lesson study process. The planning session was the first audio-recorded meeting. Following each research lesson, a debrief session with the participants took place. Each of the debrief sessions was also audio recorded. Both the planning and debrief sessions were subsequently transcribed.

Lesson Study Artifacts

The participants provided lesson artifacts for both the research lesson and the retaught lesson. These artifacts included the lesson plan created by the participant prior to the second research lesson. The teacher created student pages corresponding to the research lesson, and a nonfiction text was provided to the students as a part of the lesson. During the research lesson, the observing participants recorded data on the lesson plans and student pages provided by the teaching participant. These lesson plans and student pages were collected, along with participant feedback by the researcher following the debrief sessions for the data analysis.

The Researcher

The researcher was a key instrument in qualitative research (Creswell, 2007). She initially served as a guide to introduce the background and purpose of lesson study to the participants. She also served as a guide to help orient the facilitator with the responsibilities of her role during the lesson study process. Following facilitator orientation, the researcher served as a nonparticipant observer for the remainder of the study. At the time of the study, she had a Bachelor of Science degree in Biology and a Master of Science degree in Biotechnology. She had nine years of K-12 teaching experience, for which she was state-certified in secondary science education. She had taken several courses in educational research and a course specifically in qualitative research design. She had also assisted in several sections of a life science content course for elementary teachers that strongly focused on best practices for teaching science at the elementary level and life science content.

Procedures

This section will describe the procedures employed in conducting the study. The organization of this section is based on the order of the activities: participant selection, lesson study preparation, the lesson study process, and the lesson study closeout. A timeline of events and the corresponding data collected (see Table 6) is provided for clarity in terms of the exact time in which specific events took place. Prior to the data collection, school district approval was also granted (see Appendix J).

Table 6

Timeline of research activities

Week	Activity	Data collected
0	Meeting with the administration Initial teacher contact *State Standardized Testing (Two Weeks)*	
1	Initial teacher meeting Meeting with Knowledgeable Other	Informed Consent Writing Prompt Demographic Survey
2	Planning meeting	Audio Recordings Researcher Field Notes
3	Research Lesson 1 Lesson Debrief	Lesson Artifacts Video Recordings Lesson Plans with Teacher Observations Debrief Audio Recordings
4	Retaught revised lesson Debrief	Revised Lesson Plans with Teacher Observations Video Recordings Debrief Audio Recording
5	Post-study interviews	Written Reflections Text and Email Correspondence

Participant Selection

Prior to the official start of the study, and following the receipt of approval by the university's Institutional Review Board (See Appendix J), the researcher made contact and scheduled a meeting with a member of the administration team at the school site. The purpose of the meeting was to gain insight into the school operations and logistics to aid in planning the research lesson. The meeting also served to explain the vision of the study, answer any questions, and address any reservations that the principal might have regarding graduate student research. The assistant principal (AP) at the school was named as the research contact and building supervisor.

The AP explained the building logistics to the researcher and provided a tour that included some informal observations of live classes at all grade levels. As the tour ended, the executive principal invited the researcher and AP for a brief conference. During this time, the executive principal explained his vision for a Science Technology Engineering Art and Mathematics (STEAM) school, and the researcher gave a brief overview of the research study. The executive principal stated that this STEAM school employed a full integrative model in which the student engaged in learning, which included all subject areas simultaneously.

It was also during this time that the researcher and both the assistant and executive principals brainstormed about the best teachers to suit the needs of the research study. The researcher explained the desire to have teachers in the study with varying levels of teaching experience. The principals decided that the fourth-grade team contained the pool of participants from which they would choose, and the three potential participants were chosen in that meeting. The principals named a potential participant that they perceived as being the strongest on the team and as having the most experience, Hannah Kennedy (Pseudonym). Hannah was also a potential candidate for the Teacher of the Year Award. The next named potential participant, Christina Adams (Pseudonym), was a teacher who was also strong in her teaching practice, but the principals stated that she had less experience. The third potential participant for the study, Samantha Adams (Pseudonym), was a first-year teacher. The principals felt that she would benefit the most from a study that allowed her to observe the more experienced teachers.

The researcher asked the administration team about the need for a knowledgeable other, a non-participant with knowledge of science instruction and practice, to assist in facilitating the planning and debriefs during the study. The principals both suggested the school academic coach, Rosy Carter (Pseudonym), whose role consisted of assisting teachers in planning and implementing best practices in the elementary classroom. Rosy was not on the administrative team, and her assistance in classrooms was via invitation by the teacher and was not required (therefore, it was not evaluative in nature). For these reasons, the principals thought that Rosy would be a good fit for the study. Following the meeting, the assistant principal sent an email to the participants and the academic coach as an initial introduction and a means for the researcher to have the contact information for each of the potential participants.

Lesson Study Preparation

In preparing for the lesson study, the researcher corresponded several times with the participants, both in person and via email. She also met with the knowledgeable other and requested videos and artifacts from the teachers. The sequence in which these events occurred is outlined next.

Initial email. The researcher made official correspondence with the study participants via email. In this contact, the researcher shared a one-page summary with the basic information about the study. Moreover, she requested options for meeting times and sent informed consent documentation. The participants were requested to complete two tasks: respond to a writing prompt that was also attached to the email and submit a video of a science teaching lesson. Due to time constraints, the researcher was unable to get pre-observations of the science lessons for all three participants. To that end, the video data served to provide a sample for the researcher of the participants' current science teaching.

Meeting with the facilitator. Rosy Carter, the designated knowledgeable other, responded to correspondence from the researcher with dates for the initial meeting. She had previously met with the participants, and they had all agreed upon the date. The researcher requested a meeting with Rosy to introduce herself, orient her to the lesson study, and to explain the responsibilities of the facilitator role in the lesson study.

On the day of the initial meeting, the researcher met with Rosy first. In this meeting, the researcher provided Rosy with a proposed outline of the lesson study process. During the discussion of the format of the lesson study, Rosy noted that the planning process in which the participants regularly engaged had some distinct similarities to that of the lesson study. The researcher and Rosy then discussed the logistics and the specific role of the facilitator throughout the lesson study process. The role of the facilitator was twofold: to guide conversations so that each participant was given the opportunity to speak and to keep time.

Meeting with the participants. Following the meeting with Rosy, the researcher met with the participants for the first time. The purpose of the initial meeting was to thank the participants for agreeing to participate in the study, to familiarize them with the purpose of the professional development experience as a research project, and to be formally introduced to the researcher. The researcher also took this time to answer any questions that the participants had about the process. The participants had questions surrounding the time commitment and wanted clarification on how they would be able to complete the study in addition to the demands of testing and the end-of-year closeout. Both Rosy and the researcher assured the participants that the study design fit into their regular schedules, with minimal time needed outside of class time. The researcher described the lesson study process in detail, accompanied by a hard copy of the page that was originally emailed to them, which outlined the process for the participants and presented a proposed timeline for the data collection.

After the researcher addressed all questions, the participants were asked to review and sign the consent forms for the study. They were also reminded to complete a writing prompt (see Appendix A) and to respond to a demographic survey (see Appendix B) if they had not already done so. In preparation for the planning meeting, the participants were asked to review their current practices in science teaching, along with the lessons and activities that they had previously used, and to select a lesson to share with the group. To conclude this meeting, the group decided on a time for the lesson study planning meeting. The participants were in the process of preparing their students for state testing, so the agreed-upon time to meet immediately followed the close of the state standardized testing window.

Lesson Study Process

A lesson study cycle follows a general iterative process, as depicted in Figure 3. This process consists of a goal-setting and lesson-planning phase, teaching of the research lesson, a debrief following the research lesson, and reteaching. The following sections discuss the procedures associated with the lesson study process

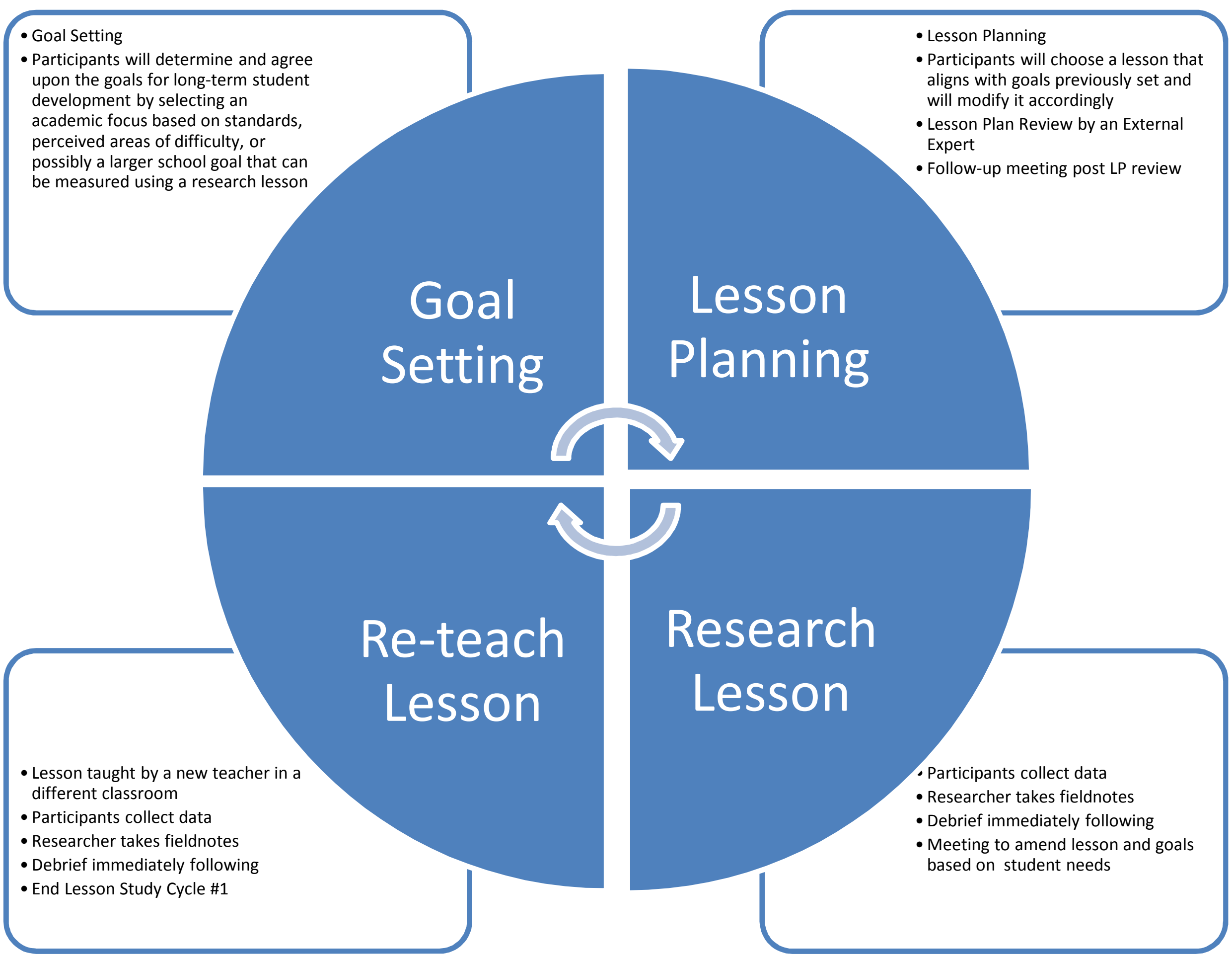


Figure 3. Lesson study cycle for the study.

Goal setting and lesson planning. The second meeting of the lesson study group was the official beginning of the first lesson study cycle: the goal-setting and lesson-planning phase. The planning meeting took place at the close of the standardized testing window and was two-and-a-half weeks after the initial meeting. The originally scheduled time for the meeting was after school. However, it was subsequently rescheduled for a time prior to the start of the school day and was shorter than expected due to the participants' prior obligations to professional development outside of the school building that day. The meeting was audio recorded and facilitated by Rosy. At this point, the researcher only recorded fieldnotes and offered no comments during this meeting.

During the planning meeting, Rosy led the participants in choosing a State Science standard for the fourth-grade lesson, setting a goal, and deciding on how they would assess students in meeting that goal. The participants chose a standard that they felt the students did not grasp fully when it was taught earlier in the school year. Rosy agreed on the standard and talked with teachers about how to remediate the standards that had been previously addressed, while building a foundation for the skills that the students would need in the fifth grade. Rosy asked the teachers to think about how they wanted to reteach this standard, and brainstorming ensued. Each participant contributed her thoughts, with some speaking more than others.

Once the group agreed upon the standard to be taught and the goal to be addressed, they discussed who would be responsible for teaching the first research lesson. The group decided that Hannah would teach the first lesson, while the others observed and collected the data. Hannah accepted the nomination. She agreed to write a lesson plan and send it to the other participants for edits. Prior to the conclusion of the meeting, a date was set for the lesson to be taught. During this session, the researcher recorded fieldnotes.

Research lesson teaching and observation. On the day of the research lesson, the researcher arrived at the school with substitute teachers to cover the classes of the participants who were collecting the data. After each substitute was placed, the participants and knowledgeable other convened in Hannah's classroom, where the researcher began to video record the lesson. Although everyone met in Hannah's classroom, the class was moved to the lobby area near the greenhouse where the lesson would begin. The bulk of the lesson was designed around making observations about the greenhouse and how the sun's energy was converted into other types of energy. For this reason, Hannah felt the need to have her students meet just inside the lobby area. Once everyone arrived, the lesson was framed by noting that, "We are not here to study or argue about global warming" (Research Lesson 1, 05/02/17). This was followed by a brief question-and-answer session to activate the students' prior knowledge regarding the purpose of a greenhouse.

Hannah also made a connection to the functionality of the greenhouse in comparison to the Earth's atmosphere. Following the conclusion of the lesson introduction, the students exited the building to go to the greenhouse. As the lesson was progressing, the other participants and Rosy were collecting data on the lesson plan and the packet that the students were given prior to the start of the lesson, which was provided by Hannah. The participants were then directed to determine who (among themselves) would focus on teacher action and voice and who would focus on the voice and actions of the students.

The students recorded information on their data sheets before, during, and after entering the greenhouse. The students lined up outside of the greenhouse to make observations about the current weather conditions. A discussion was led comparing the day's weather to that of the previous day and its potential impact on the functionality of the greenhouse. The students then entered the greenhouse to collect and record more data and answer questions the teacher had posed. Neither the researcher nor the other participants entered the greenhouse due to the lack of available space; however, the teacher and students' conversations could still be heard from outside. Hannah conducted a question-and-answer session for students once the data collection had concluded in the greenhouse, and they completed the lesson outside of the school building on the sidewalk facing the greenhouse. During the research lesson, Rosy received a call from her daughter, who was home sick, and, thus, she was unable to finish her observation of the research lesson. Nevertheless, she did leave feedback to be shared in the debrief session. Because of the transient nature of the lesson design, the researcher was unable to collect fieldnotes and simultaneously video record the research lesson. To this end, the researcher added voice notes to the video of the participants teaching.

Research lesson debriefing. The teachers decided to debrief immediately following the first research lesson. Because Rosy had to leave, Christina was designated to be the facilitator of the debrief. The researcher decided to hold Rosy's notes until the end so that they would not influence the participants' responses. Prior to the start of the debrief, the researcher gave Christina an overview of the facilitator's job and set the norms for the debrief session. For the rest of the meeting protocol, the teacher who taught the lesson was the first person to share first about the experience and to include those things that she thought went well and what things she might change. Following that reflection, the other participants then shared their feedback from the data that they collected. After sharing their data, Christina shared what Rosy had recorded in her data collection.

After all of the feedback was given and received, planning began for the lesson to be retaught and adjustments were made to both the lesson plan and the student data pages based on the data (i.e., participants' notes and feedback collected during the research lesson). The participants decided that Samantha would reteach the lesson to her students for the second round in the lesson study. Hannah and Christina offered suggestions for edits to be made to the lesson, since Samantha's group of students had different needs than the students in Hannah's class. The participants suggested edits to the student sheet, based on confusion shown by the first group of students. Additions were also made to the student data sheet in the student packet to account for missing information that was perceived to be important. Samantha took note of every suggestion made by the more experienced teachers, and she agreed to make these changes prior to the next meeting. The lesson was taught on a Friday, and due to schedule conflicts, the time agreed upon to reteach the lesson was the following Monday. Samantha stated that the next meeting date was feasible and would allow adequate time to prepare for and make the necessary adjustments to the lesson by the following Monday.

Retaught lesson. Samantha emailed a copy of the lesson with adjustments to the participants, the researcher, and Rosy on Sunday evening. On Monday morning, the researcher again reported to the school with the substitutes to cover the observing participants. All observers met in Samantha's classroom. Samantha chose to begin her lesson in her classroom rather than moving the students to a location outside right away. The first thing that she did was introduce the learning objectives for the day to her students. During this time, she led the students in a discussion to deconstruct the learning objective into the *what* and *why* of the lesson. Afterwards, the teacher reviewed the article accompanying the lesson with the students in order to check for understanding and reading comprehension and to fill out part of the table on the student sheet before moving outside. Prior to moving to the greenhouse, Samantha led the students in a discussion about the difference between an observation and an inference. She used the whiteboard and chart paper in her classroom to draw a model of the greenhouse as her students told her each part and how it was analogous to each part of the atmosphere. This was done in observance of the recommendations from the other participants in the last debrief session.

Once the students finished their initial recording and article reflections, they lined up to go outside to the greenhouse. The students entered the greenhouse to make and record their observations. Once the data collection concluded, the students met with their partners to compare notes and complete the data tables. Upon completion of the data tables, the students were then escorted back to the classroom to finish the class discussion.

The observing participants collected data and their recorded observations at each point of the lesson (based on their assigned roles, as in the first lesson). The researcher began video recording but ran out of battery power just as the class was making a transition to the greenhouse. Thus, voice-recorded notes were used to collect data in lieu of the video recording of the second half of the research lesson.

Final debriefs. The participants decided again to debrief immediately following the lesson. In this session, no facilitator was assigned from the participants in the group; in addition, Rosy was unable to attend this lesson and debrief due to a prior engagement. The researcher reminded the group about the debrief expectations, and the participants agreed. As in the last debrief, the participant responsible for teaching the lesson was given the first opportunity to reflect on the lesson. Samantha shared her thoughts, and then the other participants offered their feedback. After all feedback was shared, the participants reflected on the process of creating, implementing, and observing the lesson, followed by the opportunity to make adjustments and see that they were implemented. They then discussed how they could be proactive in using the greenhouse for data collection in the coming school year. This debrief session concluded the lesson study cycle and was audio recorded by the researcher. Field notes were also collected.

Lesson study closeout. The researcher had planned to conduct the post-lesson study interviews with each participant. After many unanswered attempts to schedule, the researcher created a guided survey reflection and sent it to the participants via email. Two of the three participants completed the close-out reflections. The researcher was later able to communicate with the final participant via text message. It was also anticipated that a post-lesson study observation would be made for each participant's classroom, but due to the time of year, the participants had finished teaching formal science lessons in order to focus on a larger school-wide project.

Data Analysis

Data for this case study were analyzed using what Creswell (2016) described as a "data analysis spiral" (p. 182). This process includes data gathering and organization, followed by coding the data collected. Once all data are coded, the process of reducing the coded data to themes follows. Finally, the results of the analysis are compiled to complete a case study report. Data were collected and organized to develop a case study database (Yin, 2013). The researcher created folders for each participant, which included all of the data collected. These data were either provided by or were specifically related to each participant. Handwritten documents submitted by the participants, in addition to handwritten researcher notes, were also converted to a PDF format and were saved in the corresponding participants' folders. These data folders were labeled with the pseudonyms of each participant and were saved in three different locations for security purposes.

Following the data organization, the researcher read through all of the written data and watched all of the videos. Moreover, the researcher took notes along the way to get a general idea or survey of the data gathered prior to beginning the coding process. All videos, both those submitted by the teachers and recordings of the research lessons, were coded using the Teaching Dimensions Observation Protocol. All written data and PDF documents were also uploaded into the data analysis software Atlas.ti (Scientific Software, 2018). Because the study aimed to explore instructional practices for the participants' science teaching, *a priori* codes (see Table 7) were developed using research on reformed science teaching (NRC, 1996, 2011; NSTA, 2018).

Table 7

Initial A Priori Codes

Initial Codes	Anti-codes	Code descriptions
Model skills of inquiry	Telling skills of inquiry	Teachers modeling inquiry skills and practices for students; teacher engages in inquiry with students
Orchestrate discourse	Inhibits discourse	Teacher support students participating in discussion or argumentation about scientific topics
Support inquiry		Actions that support students engaging in the inquiry process
Student agency and authority	Teacher responsible for learning	Students taking responsibility for their own learning

The initial codes were chosen to answer the following question: What instructional practices characterize each embedded case? The researcher began with a small list of codes that included supporting inquiry, orchestrating discourse, student responsibility and agency, equitable teaching practices, and modeling skills of inquiry. Anti-codes were added to these codes. These anti-codes represented practices that were observed and that were antithetical to reformed teaching practices. In other words, the anti-codes were representative of a more traditional model of instructional practices. These included inhibiting discourse, telling students about inquiry skills, and the teacher taking responsibility for the students' learning. Table 7 outlines the initial codes, anti-codes, and corresponding descriptions.

These codes were added to Atlas.ti and were utilized for the first round of coding in the data analysis process. All collected documents were analyzed using these codes and anti-codes. This process included reading through all of the documents in Atlas.ti and linking one of the abovementioned codes to sentences or phrases (also known as quotations) that reflected the code's description. Because the *a priori* codes were previously created and loaded into the Atlas.ti software, the researcher was able to select the codes corresponding to the quotation from a list and attach it in the document.

In addition to the codes named above, the researcher needed to distinguish between practices that were observed by the researcher and perceived practices by the participants, either about themselves or others' practices. The researcher added the codes that were perceived and observed so as to co-occur with the practices that were identified in the data. For instance, in a writing prompt submitted by one of the participants, the following quotation was selected: "Inquiry is a huge part of our science instruction as a team. Whenever beginning a new topic in science, we typically do something hands-on with inquiry" (Christina's writing prompt, May 2017). This quotation was coded in the first round of coding for support inquiry. In addition to the support inquiry code, it was also coded as perceived because the participant was writing about her own practice. Thus, this reflected how she viewed her teaching practice. An example of the codes assigned and corresponding quotations from the data can be found in Table 8.

Table 8

Example of Codes

Code	Description	Quotation from data sources
Support inquiry	Actions that support students engaging in the inquiry process	"Inquiry is a huge part of our science instruction as a team Whenever beginning a new topic in science, we typically do something hands-on with inquiry" (Christina's writing prompt, May 2017).
Orchestrate discourse	Students participating in discussion or argumentation about scientific topics	"Review Observation vs. Inference. The teacher will allow time for student feedback and discussion, and then write answers on a chart on the board" (Samantha, Lesson Plan submitted, May 2017).
Students agency and authority	Students taking responsibility for their own learning	"…they always have their STEAM notebooks to write down observations and such during their activities" (Samantha's writing prompt, April 2017).

Once all documents were coded in Atlas.ti, the codes with the highest frequency were grouped to create a network (see Figure 4). For instance, teaching practices appearing in the data that were coded for support inquiry yielded the highest number of occurrences. That code, with its corresponding quotations, was used to create a network. The networks were composed of all quotations that had that particular code attached to it. In the network, the researcher was able to group the quotations that had similar qualities.

Those quotations that were coded for support inquiry were sorted and sub-coded to reflect the teaching practice or activity that was prevalent.

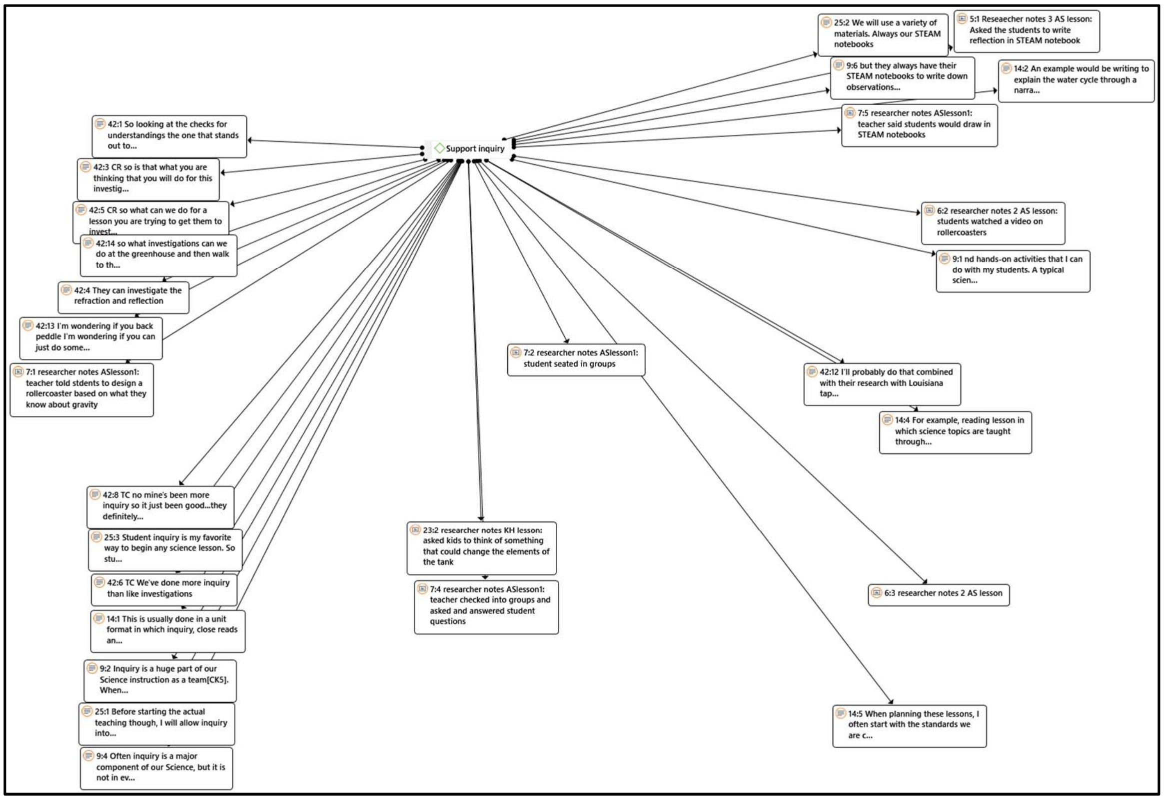


Figure 4. Example of a network created in Atlas.ti.

These sub-codes were created using the science and engineering practices from *A Framework for K12 Science Education* (NRC, 2011). These sub-codes included the following: STEAM notebook, charting data, reading articles, observations and inference, standards and purpose, investigation, inquiry, questions, terms and vocabulary, and discussion. The quotations within the supporting inquiry network were subcategorized based on the practices present, such as investigations or the use of the STEAM notebook or charting data. Once in these subgroups, the codes were created to link to all of the quotations in that group. These subcategories later became themes.

All codes for support inquiry in the network were filtered out by the participants, and subsequent networks were created showing the practices and activities that supported inquiry for each embedded case. Within these networks, the quotations were sorted based on similar characteristics; they were then labeled with a code that reflected those characteristics and qualities. All quotations within the network for each embedded case was also coded with the participant's initials for easier identification in the cross-case analysis.

A cross-case synthesis was employed to report the similarities and differences of the embedded cases (Yin, 2013). This was accomplished first by using Atlas.ti software to create co-occurrence tables for the second round of codes and embedded cases. The co-occurrence tool allowed the researcher to create a table with the initials of the participants as the column headers and codes as the row headers. The table generated the number of occurrences of each code for each participant. For example, the column labeled SA for participant Samantha Adams and the row labeled investigation yielded six occurrences, indicating that Samantha mentioned *investigation* six times in the provided documents during the lesson study.

The data were separated based on whether they were collected before or during the lesson study process, and two separate co-occurrence tables were generated. For the purpose of clarity, the tables were combined. The co-occurrence table in Table 9 shows the number of occurrences of each code for each participant, both before and during the lesson study cycle. Using this table allowed the researcher to identify similarities and differences between the embedded cases, and any changes that occurred from the onset to the conclusion of the study.

Table 9

Co-occurrence Table Comparing Practices, Both Before and During the Lesson Study Cycle

	Before Lesson Study			During Lesson Study		
Codes	HK	SA	CT	HK	SA	CT
Charting data	0	0	0	11	6	5
Discussion	1	1	0	1	0	8
Equitable teaching practice	0	3	1	1	0	1
Inquiry	0	2	2	0	0	0
Investigation	0	0	0	6	6	2
Observation/Inference	0	0	0	4	3	4
Orchestrate discourse	1	3	0	11	7	6
Purpose/Standard	2	1	1	1	4	3
Question	1	1	0	4	4	1
Reading articles	3	0	0	6	0	0
STEAM Notebook	0	3	0	0	0	0
Student agency and authority	1	6	0	9	5	5
Support inquiry	5	11	3	27	26	23
Terms and vocab	0	1	0	0	4	0
Videos	0	3	0	0	0	0

At the conclusion of the coding, the researcher began the process of describing and classifying themes, and a series of data-sorting processes began. The first filter was completed at an earlier stage when the data were sorted based on embedded cases. To begin the second round of coding, all quotations from all documents in Atlas.ti were filtered for each participant and placed in a network; these quotations were subsequently sorted by common characteristics. The next phase of sorting included sorting quotations based on time related to the lesson study process. The documents and data sources that were collected prior to the start of the lesson study process were separated from those that were collected during the lesson study process. Those documents, writing prompts, video lessons, and researcher notes were used to develop themes characterizing each embedded case's typical individual teaching practices. All documents and data sources collected during the lesson study process were used to identify themes characterizing the entire group or holistic cases. Those data sources included the lesson-planning meeting transcript, lesson plans for the research lessons, observation data collected by the participants during the research lessons, and transcripts for the debriefing sessions. All quotations from documents during the lesson study were compiled to create a network. This network of quotations was sorted based on similar characteristics and were coded to identify common themes.

Following the analysis process, detailed case descriptions were written for each participant, which described her individual teaching practices in science and how these practices were present or absent during the lesson study process. The Inquiry Continuum (NRC, 2000) was utilized to categorize each participant's instructional practices prior to engaging in the lesson study process based on reform-oriented science inquiry practices.

This categorization was accomplished by analyzing the video data submitted prior to the start of the lesson study using the continuum. Next, a holistic case narrative was presented, which defined the characteristics of the teaching practices regarding the collaborative group during the lesson study process. The Inquiry Continuum was again used to categorize the instructional practices enacted by the group while implementing the research lessons. A cross-case analysis was also included that described how each participant's individual teaching practices influenced the lesson study process.

Limitations of the Study

This study had several associated limitations. These limitations included: (1) the length of the study; (2) meeting time changes with short notice; (3) teacher commitment level; and (4) limited opportunity for the post-lesson study data collection. Generally, lesson studies happen over an extended period (Lewis et al., 2004). Because the researcher was working with in-service teachers, the study time was limited to the school year. The data collection phase began in the last semester of the school year near the state standardized testing window, which lasted between two to three weeks. The researcher was not permitted to begin formal data collection until the testing window was completed. This restriction allowed an extremely small amount of time for the researcher to conduct the lesson study and collect the data for the case study.

Participant commitment was another limitation. At the onset of the study, the researcher received correspondence from one participant on behalf of all the participants voicing concerns about the requested materials, stating that the time commitment was more than originally agreed upon. The researcher assured the participants that this process would fit into their daily routine, with a minimal time commitment outside of class. The participants were reminded to submit their demographic surveys, writing prompts, and video lessons at every meeting, but only one participant submitted these at the requested time.

Each meeting time was prescheduled with the participants. On two separate occasions, the meeting times were changed with one day's notice. The planning meeting was changed from a time after school to a time before school on the day immediately before the originally scheduled time. The before school time caused the meeting to be shortened. This may have adversely influenced the quality of the planning session. This also happened after scheduling the first research lesson.

The final limitation may have resulted from the aforementioned limitations. The original study design included a collection of the post-lesson study data. Despite many efforts on the part of the researcher, due to the time constraints and a lack of teacher commitment, the post-lesson study data were not collected. Following the last debrief session, it was difficult for the researcher to correspond with the study participants for post-interviews and reflections.

Delimitations of the Study

The following factors in the study could impact the results and were controlled by the researcher thus making them delimitations. First, the participants chosen were all fourth-grade teachers, in the same school. Next, the context of the study was selected by the researcher to be an elementary STEAM school. Finally, the researcher chose to use a knowledgeable other in the planning and implementation of the research lesson. Therefore, although the results of this study may provide insight into the use of lesson study in elementary science contexts, these decisions may affect transferability into other settings.

Trustworthiness

The researcher employed techniques to ensure validity and transferability of the study (Creswell, 2007). In an effort to increase the validity of this study, multiple and different data sources (e.g., observations, video transcriptions, fieldnotes) were utilized, and each participant checked the embedded case narratives. To support transferability, a rich description of the research context and study participants was provided.

Chapter Summary

Observing the participants' instructional practices in their natural setting as they taught science lessons was the primary focus of the case study. The use of lesson study served to facilitate collaboration among the participants as they engaged in goal setting, lesson planning, research lesson observation, and debriefing. Following the lesson study cycles, the researcher analyzed the data to determine whether engaging in lesson study had any impact at all on teacher practice at the elementary level. In this chapter, the researcher provided the research context, information regarding the participants, instruments and data sources, procedures, data analysis, limitations, delimitations, and issues of trustworthiness.

CHAPTER FOUR: RESULTS

Introduction

In the U.S., traditional elementary science instruction has not supported young children's engagement in sophisticated scientific practice, nor has it facilitated their ability to deeply understand science concepts (Banilower et al., 2013; Trygstad et al., 2013; Weiss et al., 2003). Studies have shown that student interaction with science content is limited at best (Roth & Givvin, 2008; Weiss et al., 2001). This is inconsistent with the science reform efforts set forth in *A Framework for K-12 Science Education (*NRC, 2011) and the original mandates of the National Science Education Standards (NRC, 1996), which encouraged reformed teaching methods. This inconsistency in elementary science education led science educators to note the importance of the teacher's role in student achievement and the potential role of effective professional development in this endeavor (Desimone et al., 2002). As a professional development tool, lesson study is a means for teachers to scrutinize and improve their instructional practice (Lewis et al., 2006). Further, lesson study allows teachers to look inductively at their current practice and work through an iterative process to improve that practice, thereby improving student achievement (Lewis et al., 2006).

The researcher employed an embedded case study design (Yin, 2013) to examine the potential of engagement in lesson study in supporting professional development for elementary science teachers. The current study specifically sought to explore the typical science teaching practices of a group of fourth-grade teachers, compared to their teaching practices in a research lesson of a lesson study cycle. An analysis of each embedded case allowed the researcher to notice similarities and differences in the instructional practices of each participant. A cross-case analysis was also conducted, which allowed the researcher to recognize patterns that arose during the planning and implementation of the research lessons in the lesson study cycle.

In this section, case narratives provide a rich description of each embedded case prior to engaging in the lesson study. A description of each participant, including their demographic information and their individual teaching practices prior to engaging in the lesson study process, is provided. For each case, the themes characterizing the teaching practices of the individual participants, as well as how those practices aligned with the essential features on the Inquiry Continuum (NRC, 2000), are discussed. Next, a narrative of the lesson study process and a cross-case analysis describing how the participants' individual teaching practices influenced the lesson study process is included. Finally, an analysis is included with respect to how the teaching practices enacted by the group of participants, or the whole case, were aligned with the Inquiry Continuum (NRC, 2000), as well as any changes in instructional emphasis by the embedded cases along the continuum.

The Case of Hannah Kennedy before the Lesson Study

Hannah Kennedy (Pseudonym) was one of five teachers on the fourth-grade teaching team. Hannah was selected by the administrative team to participate in the study based on her past contributions to and leadership of the fourth-grade team. She held a Bachelor of Science in elementary education and a Master of Science in education. At the time of the study, she had been teaching for four years, all of which were at the fourth-grade level. Hannah described her class demographics as follows:

> My class for the 2016-17 school year was a gifted cluster group. One student in the class has a gifted IEP. Approximately 75% of the class could be classified as above average students. There are a few students who could be classified as average or below average students academically. (Demographic Survey, 4/20/2017)

In preparation to teach science content for the school year, Hannah noted that she attended two science-specific professional development sessions in which she participated in science standards exploration in conjunction with other teachers in her building.

In order to establish a representation of each participant's individual teaching practices, the researcher asked the teachers to complete a writing prompt (Appendix A) that described a typical science lesson in their classrooms. The teachers were asked to describe the planning, implementation, and assessment processes employed in teaching a science lesson. They were also asked to include the materials used, sources of the lessons, and the types and lengths of activities. In addition, the researcher requested that each teacher provide a video of a science lesson that was taught by the teacher in her own classroom to show how she typically taught science. The TDOP was used to determine the types of materials and strategies executed in Hannah's classroom. In the following section, the writing prompt submission is discussed, followed by the results of the TDOP analysis involving the video lesson.

Writing Prompt Submission

Hannah's science lesson planning began with a non-science standard, and the planning was typically done collaboratively with other members of the fourth-grade team. When asked about her lesson-planning process in the writing prompt, she responded:

> When planning these lessons, I often start with the standards we are currently focusing on in reading and math [and] then look for connections to the science standards that I can teach in conjunction with the article I am using. For example, a reading lesson in which science topics are taught through current events or science articles, or math lessons with cross-curricular components. Since we are a STEAM school, integration is a key component of instruction. (Writing prompt submission, 5/7/2017)

The full integration of science content into other subjects was central to lesson planning and implementation for Hannah, including reading, mathematics, or social studies via current events.

Videotaped Lesson

In addition to the writing prompt, the researcher requested that each participant submit a video of a science lesson taught in their classrooms. Hannah provided the requested video of a science lesson to the researcher, which was a total of approximately 42 minutes over two days. Most of the provided lesson (28 minutes of the total 42-minute lesson) was taught on the first day, and the remainder of the lesson concluded on the following day.

Day one. In the video that Hannah submitted, the lesson aimed to build background knowledge so that the students could define a system in nature and identify the elements that form a system. The students were all seated on the floor facing the teacher as she wrote and drew on a mobile whiteboard (see Figure 5). Hannah stated that the lesson would begin with the whole group, and later the students would go back and work in small groups on a cross-curricular project that they had been previously working on. She began the lesson by asking, “Who can tell me what a system is?” (Science lesson, 5/4/2017).

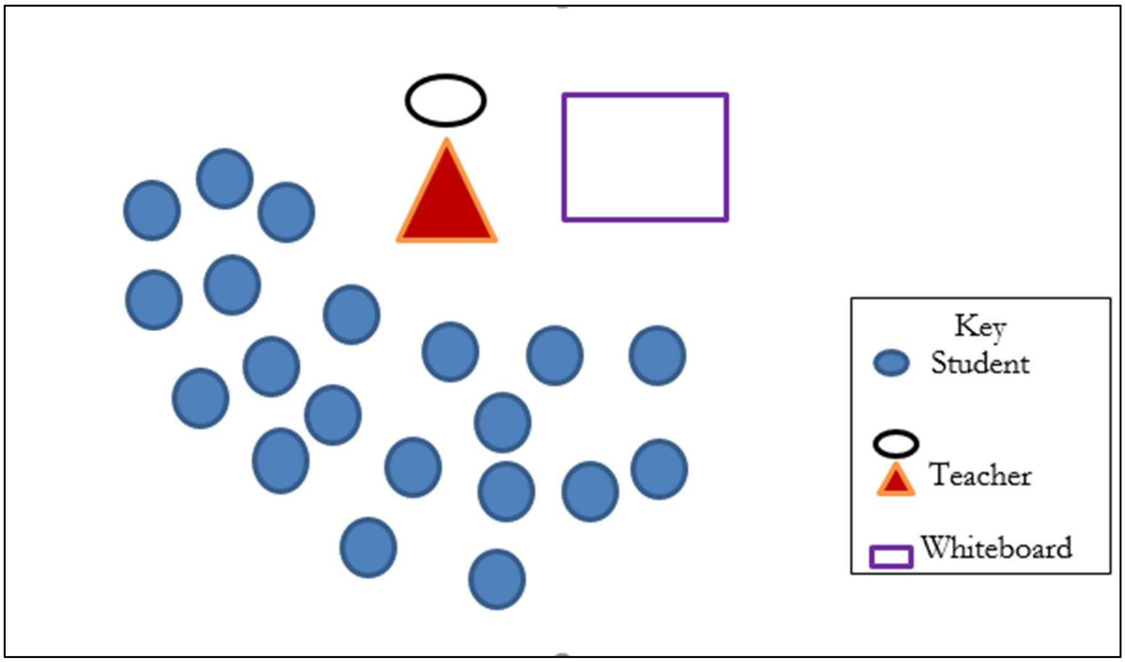


Figure 5. Seating chart of Hannah’s class during a science lesson on Systems in Nature.

Hannah stood at the board, asking questions and accepting responses until the students had provided the definitions and descriptions of the supporting terms of a system. The lesson began as follows:

1-11 Hannah: All right, so today we are building on our Louisiana Project like we talked about before. I want everyone to direct their attention over here, because this is going to be whole group at first, and then you will go back into your Louisiana groups and some things with them that you will see connected here in a moment. So, who can tell me what you know about the word *system*? What is a system?

1-12 Student: Something that you do every day that repeats like a pattern.

1-13 Hannah: OK, so there is pattern involved in a system.

1-14 Student: A system has steps.

1-15 Hannah: OK. A system has steps.

1-16 Student: It's basically like, you know how machines have systems?
They follow what is meant to do. Say there is a system to (Pause)

1-17 Hannah: OK, so it follows a series of steps often. OK.

1-18 Student: (Inaudible)

1-19 Hannah: OK, so you're saying? What I hear you saying is that systems vary depending on the purpose. So, there's a system that has this set of boundaries and outcomes, and there's a system that would have a completely different set of boundaries? OK. Let's think about a system that we all know and love or hate. Let's talk about an aquarium. Is an aquarium a system?

1-20 Student: Yes.

1-21 Hannah: So, let's see if we can revise our definition based on some of these words that we have out here (Pointing to a list of terms on the board). So, we've already talked about a system just a little bit: We're going to come back to that. What are the boundaries of our system here? What would you say are the boundaries of our aquarium? (Students' hands are raised. Hannah calls on a student.)

1-22 Student: Umm, maybe the glass on the outside.

1-23 Hannah: OK, so, the glass on the outside. What else?

1-24 Student: Security guards on the outside that are like protecting people from like getting in.

1-25 Hannah: Well, we're talking about like a fish tank at home. I don't know about you, but mine does not have security guards, but if you're somewhere like Sea World and there's a gigantic aquarium, that might be the case (Calls on another student).

1-26 Student: You have to learn how to filter.

1-27 Hannah: Is it a boundary? So, let's talk about the definition of a boundary. What is a boundary? (Calls on a student) What's a boundary?

1-28 Student: The boundary is like the outside. You have to stay inside the edge.

1-29 Hannah: OK, so it indicates a limit? (Points to the diagram of the aquarium) So, there are some things in here that can't go past that boundary. It indicates a limit or a border (As she reads from a paper). You agree with that?

1-30 (Students all nod in agreement)

Students continued to offer definitions to the terms listed on the board as they related to the system, an aquarium. With each student response, Hannah validated the student by repeating or clarifying what was shared, and she asked for another student to add his or her definition of a system or to define an associated term. Hannah and the students concluded that the definition of a system consisted of the interactions between living and non-living things. Once the whole group portion of the lesson ended, the students were dismissed to return to their smaller groups to work on a different part of their projects.

To conclude the lesson on day one, Hannah asked the students to use what was concluded about systems and the elements that influence them in relation to the Louisiana Project that they were working on. The conclusion of the day one lesson proceeded as follows:

1-19 Hannah: Let's pause this conversation, and you're gonna get with your Louisiana groups, and I'm gonna give you a graphic organizer. I want you to start talking about with your groups [about] the system that was New Orleans and Louisiana. Was there an element introduced into that system within your realm of research? So, for instance, Lilly's group has the Louisiana Purchase. What element changed as a result of the LA Purchase?

1-20 Student: (Inaudible)

1-21 Hannah: But what happened? How did that change for the elements already in our system in Louisiana?

(Wait time)

1-22 Hannah: The U.S. did gain more land, but how did the influx of that population change? I mean that was an input, right? So, we had an input into our system, the population, the people who lived in other places in what was the U.S. at the time the population grew down in Louisiana, so things changed. Some of you have like interdependence and food webs and food chains that you are researching. That's a textbook example of a system. So, what is something that has changed? So, we've specifically talked a lot about Hurricane Katrina, so think about what that input changed as far as the system that you are currently researching. OK?

1-23 Student: Are we going to research a little bit more?

1-24 Hannah: Yes. Yes, you're going to have an opportunity, you're going to start with a graphic organizer, and then you are going to have a chance to research a little bit more, and then we are going to come back to close out our lesson. Does everybody see where this is going? Can you envision the boundary of your system? Can you envision the elements of your system?

1-25 Students: Yes.

1-26 Hannah: All right, go to your tables with your STEAM group and I'll be coming around with your handout, OK?

This concluded the lesson for the day, which then resumed the following day.

Day two. On the second day, Hannah continued the lesson that she began the day before on systems. The seating configuration was just as it was the day before, with the students seated on the floor in front of the mobile whiteboard on which Hannah had diagramed the system of the aquarium (see Figure 6). In this portion of the lesson, the focus was to connect the lesson on a system and the interactions within it to the larger cross-curricular project that the class had been working on, which she referred to as the "Louisiana Project."

Figure 6. Diagram created by Hannah during the discussion of a system.

The lesson resumed as follows:

2-1 Hannah: All right, so, we are going back to our system that we started discussing yesterday. Um so, let's kind of refresh our memory and talk about the systems that we already know about from our science standards. So, who can share a system that comes to mind that we've already studied in science this year?

2-2 Student: Having to go through the engineering method with our STEAM projects?

2-3 Hannah: OK, so our engineering process is a system? Yes.

2-4 Student: Food chains and food webs.

2-5 Hannah: Absolutely, food chains and food webs are part of a system. Umm, do those change depending on the location of the system?

2-6 Student: Yes.

2-7 Hannah: Sure. Which is an element that is a part of that system? Absolutely. . .

2-8 Student: Water cycle.

2-9 Hannah: Ahhh, the water cycle is a system. Now does the water cycle affect other systems, yeah absolutely (Student)? What else?

2-10 Student: Adaptations.

2-11 Hannah: Tell me more.

2-12 Student: Ummm, like when we were studying how the animals adapted to their environments?

2-13 Hannah: OK, so, if the animals adapt to their environment, is that it? Is that, does that make that adaptation a part of the system, or is that in response to an element in the system? What do you think?

2-14 Student: Response (then inaudible)

2-15 Hannah: OK. I agree. Tell me why you say that.

2-16 Student: Well, because you have to adapt to where you are, and that's one of the only ways. It's kind of the only reason you adapt.

2-17 Hannah: OK. I agree with that. I think that's a good analysis. OK, so we've been studying Hurricane Katrina and the Louisiana purchase and basically the swamp marshlands of Louisiana. Ummm, so, tell me what you guys decided with your groups, what kinds of a-ha moments you had looking at your systems? Looking at the inputs of the systems and the outputs or the umm or the negative impact that we had, so tell me your a-ha moments with your groups. (Student)?

2-18 Student: I noticed that interactions that there was in the system of our system that was a (Inaudible).

2-19 Hannah: OK, so tell me about some of the predator-prey relationships in your system of Louisiana.

In this portion of the lesson, Hannah asked students to reflect on the discussions in their groups and share any discoveries that they had as a result of the lesson on systems that related to their bigger project. This whole-group dialogue continued for about 12 minutes before Hannah dismissed the students to return to their tables in their Louisiana groups to continue working on their projects with the additional knowledge about systems.

TDOP analysis. Each of the basic dimensions contained codes that determined whether the interaction or instruction was teacher- or student-centered. On day one of Hannah's lesson, she began with a lecture. Thus, the first interval was coded for a lecture only. She later began to write and draw on the board and continued to do so throughout the duration of the lesson. Due to the configuration of the students' seating arrangement and the constant exchange of dialogue between the teacher and the students, the researcher also coded for a Socratic lecture as an instructional method. In the teacher-focused dimension, lecture while writing (LW) was coded for 79% of the intervals and Socratic lecture (SL) was coded for 100% of the intervals. The dialogue between the students and the teacher was consistent throughout the entirety of the lesson.

On the TDOP, teacher-led dialogue is divided into the types of questions that are asked to the students. Instructor display questions (IDQ) or questions requiring a specific answer were coded for 100% of the intervals. On day one of Hannah's lesson, the data indicated that the instruction was largely teacher-focused. For each interval, the primary teaching method was lecturing, whether it was lecturing while writing or a Socratic lecture. The students were positioned in a whole group manner around the whiteboard seemingly to create an environment for discussion. Hannah asked several questions during each two-minute coded interval to which the students provided responses. All questions were coded as display questions due to the nature of the questions and the types of responses solicited. Example questions are provided from the lesson transcript.

1-11 So, who can tell me what you know about the word *system*? What is a system?

1-13 OK, so there is pattern involved in a system?

1-19 Is an aquarium a system?

1-19 Is it a boundary? So, let's talk about the definition of a boundary. What is a boundary? (Called on a student). What's a boundary?

1-22 A boundary in a system like a farm could be a what?

1-32 What are some elements that we are going to add to our fish tank?

(Hannah's day one transcript, May 2017)

The researcher observed that the questions posed by the teacher were all closed questions. The origin of the questions was indicative of a teacher-centered methodology because all questions were generated by the teacher and none by the students. The overall lesson demonstrated teacher-focused instruction with teaching methods that did not draw on student-centered strategies or practices.

The instructional technology dimension was coded continually for whiteboard use, which was the only technology used throughout the lesson. Hannah utilized the whiteboard to draw and write as she asked questions and accepted responses from the students concerning a system. The primary teaching method that Hannah used in the lesson was lecturing while writing, coded as LW. As the students offered the elements of the system in an aquarium, Hannah would add them to the board.

Content Integration and the Use of Reading Articles

A major theme that characterized Hannah's teaching practice prior to engaging in the lesson study process included the need to integrate science instruction into other content areas. Hannah seemed to place emphasis on science content integrated into other content areas, particularly in reading. She mentioned in her writing prompt, "When planning these [science] lessons, I often start with the standards we are currently focusing on in reading or math, then look for connections to science standards that I can teach in conjunction with the articles I am using" (Hannah's writing prompt, May 2017). This was a recurring theme throughout the writing prompt. She also stated, "A typical science lesson in my classroom is integrated into other content areas" (Hannah's writing prompt, May 2017). Later she offered an example of how she would assess students in science using writing.

> Assessment in science is often also integrated into other content areas. An example would be writing to explain the water cycle through a narrative from the perspective of a water droplet or reading a passage on a science topic we have been covering and responding to accompanying questions. (Hannah's writing prompt, May 2017)

Another theme that characterized Hannah's teaching practice prior to engaging in lesson study was the use of nonfiction texts, which she referred to as "articles," for science instruction. The method that Hannah chose to teach science content usually included a nonfiction reading option. In the description of her science teaching practices, she listed *close reads* as one of her strategies, along with inquiry and experiments (Hannah's writing prompt, May 2017). When describing a typical science lesson, she referred to using reading lessons in which science topics are taught through current events or science articles (Hannah's writing prompt, May 2017). Integrated in the process of planning a science lesson, she stated, "When planning these lessons, I . . . look for connections to science standards that I can teach in conjunction with the articles I am using" (Hannah's writing prompt, May 2017).

The data revealed an emphasis on content integration and the use of nonfiction reading materials, which Hannah referred to as "articles," as major themes that characterized Hannah's teaching practice in her science classroom. The researcher noted that the teaching practices reported by Hannah in the writing prompt and the enacted teaching practices observed in the submitted video were partially congruent. In the lesson that Hannah submitted, there was no direct integration of science content into another content area, such as reading or mathematics, but rather a standalone science lesson was submitted to the researcher as evidence of typical science teaching in her classroom. The second day of the lesson showed some integration as she encouraged students to apply what they had learned in the systems lesson to the Louisiana Project on which they had been previously working. There was also no use of or reference to a nonfiction text supporting the lesson that was enacted.

Inquiry Continuum

Using the data collected for Hannah prior to engaging in lesson study, the researcher was able to determine where Hannah's instructional practice landed on the Inquiry Continuum (NRC, 2000), based on the essential features of inquiry (refer to Table 8). Only the first two essential features, which focus on student engagement with questions, were present in Hannah's data prior to engaging in the lesson study. In her enacted video lesson, students answered questions that were posed by her regarding the science content that was being addressed. Hannah's typical science instruction (based on the video lesson) landed on the less student-directed and more teacher-directed end of the spectrum for essential feature one, which states, "The learner engages in scientifically oriented questions" (NRC, 2000, pg. 6).

The video data aligned with the fourth column of the continuum provided in Figure 7 which addresses the origin of the questions with which the learner engages, with these having been posed by the teacher. The writing prompt gave little to no indication of engagement in inquiry practices that could be measured using the continuum. A summary of Hannah's instructional practice, compared to the continuum prior to engaging in the lesson study cycle, can be found in Figure 7.

Essential Feature	Variations			
1. The learner is engaged in scientifically oriented questions.	The learner poses questions.	The learner selects among questions; poses a new question.	The learner sharpens or clarifies a question posed by teacher, materials, or other sources.	The learner engages in questions provided by teacher, materials, or other sources.
Hannah's Instruction				X
	More-----------Amount of Learner Self Direction-----------Less Less--- Amount of Direction from Teacher or Material --- More			

Figure 7. Hannah's practice on the Inquiry Continuum before lesson study.

The Case of Samantha Adams before the Lesson Study

Samantha Adams (Pseudonym) was a Caucasian woman and the newest member of the fourth-grade team at Middleview Elementary. Samantha was nearing the end of her first year of teaching at the time of the study. She received a bachelor's in education and began teaching immediately thereafter. Samantha described her class as follows:

> I have one student who is learning English, two resource students, and a few [students who have] 504's for ADHD. [The other participants] have the two gifted classes in the grade, and I have a class with lower ability students. Although I have several high-achieving students, the majority of my class is average and well below average. (Demographic survey, 4/20/2017)

Samantha began her description of the composition of her class by describing the students via their special designations (i.e., English proficiency, exceptional education, and disabled) and then via describing the classes of the other participants as gifted.

Writing Prompt

The researcher requested that each participant submit a writing prompt and describe the planning, implementation, and assessment processes associated with science teaching in her classroom. Samantha stated the following about her science teaching:

> When beginning to plan a science lesson in my classroom, I first begin by breaking down the standards. This is sometimes done as a team, and sometimes done individually. We often try and incorporate our science lessons with other subjects, usually our reading block. When planning a lesson, I typically begin by looking for reading passages that I can use in my reading block and hands-on activities that I can do with my students. A typical science lesson has many different components: whole group instruction using anchor charts, videos, and passages, as well as group activities. Inquiry is a huge part of our science instruction as a team. Whenever beginning a new topic in science, we typically do something hands-on with inquiry. For example, when introducing circuits, I simply placed a box with the materials to build a circuit on each table without any directions and simply let the students explore the items. At the end of each lesson, I also like to have some sort of exit slip to use as an informal assessment to see what needs to be retaught, etc. (Writing prompt, 4/20/2017)

Evidence of the aforementioned statement was observed by the researcher when reviewing the lesson submitted by Samantha regarding her teaching practice.

Videoed Lesson

Samantha also submitted a video of her science teaching to the researcher. Her lesson lasted approximately 50 minutes and was interactive and collaborative. The lesson was an application lesson for the previously taught science and engineering unit addressing force and motion standards. At the onset of the lesson, Samantha had the students seated on the floor around the board as they dissected the standard to determine the goal of the lesson for that day. Samantha asked the students, “What is the *why* and *what* of today’s lesson?” (Engineering Lesson Field notes, 5/02/2017). Following this discussion, the students watched a video about rollercoasters. At the conclusion of the video, Samantha asked the students, “How are force and gravity affecting the riders?” (Engineering Lesson Field notes, 5/02/2017). A couple of students offered a response before Samantha added, “Force and gravity are similar but two different things. Gravity is the force that pulls you down” (Engineering Lesson Field notes, 5/02/2017).

As a culminating project, Samantha’s class was tasked with designing a theme park for the STEAM unit. The goal of the lesson on that day was for students to design and test rollercoasters in collaborative groups using the materials provided as they explored the concepts of force and gravity. Following the video discussion, Samantha posed the following challenge to the students: “Use the knowledge you have about force, motion, and gravity to design and build a rollercoaster to be able to carry a marble from point A to point B” (Engineering Lesson Field notes, 5/02/2017). After the challenge was posed, Samantha allowed students to ask questions about the task that had been given to them. After all directions were clear to the students, Samantha described the materials that were provided to complete this task, and the students returned to their table teams to complete the task.

The students were given a set amount of time to complete the task of designing and building the rollercoaster. Samantha circulated the room answering questions and redirecting students as necessary. When questions arose, Samantha offered only some of the desired information so that the students would come to the conclusion on their own. The class was noisy and messy as the groups discussed and worked to build their rollercoasters. Students talked to each other about the projects and worked to complete them. At the conclusion of the work time, Samantha gathered the students together to close out the lesson before the end of the class day. Upon observation, the students appeared engaged in the day's science learning activity. There was no TDOP analysis of this lesson because the videos were removed from YouTube by the teacher prior to the close of the study.

Emphasis on Supporting Inquiry using a Variety of Teaching Methods

A major theme that emerged in Samantha's teaching practice prior to engaging in lesson study was teaching with a variety of teaching methods. In her writing prompt, when asked to describe her planning process, she stated, "When planning a lesson, I typically begin by looking for reading passages that I can use in my reading block, and hands-on activities that I can do with my students" (Samantha's writing prompt, 4/20/2017). Samantha went on to share, "A typical science lesson has many different components: whole group instruction using anchor charts, videos, and passages; as well as [small] group activities" (Samantha's writing prompt, 4/20/2017). When Samantha reported on her implementation of a typical science lesson she stated:

> The implementation of a typical science lesson usually begins with some sort of whole group instruction of the new terms, etc. using anchor charts, a short video, or discussion. This is typically no more than 15 minutes . . . in every science lesson I try and incorporate some sort of small group activity, which takes up the majority of the lesson time. I have my students grouped heterogeneously by

> ability level and allow them to work on various tasks with their table mates. Materials differ based on the standard, but they always have their STEAM notebooks to write down observations and such during their activities. (Samantha's writing prompt, 4/20/2017)

These statements supported the use of various activities and teaching strategies in Samantha's typical science teaching practice.

Another theme that emerged from the data prior to Samantha engaging in lesson study was the use of inquiry as a means of science instruction. Inquiry was one of the teaching methods that she mentioned the most when she discussed her teaching practice. Samantha described inquiry as such during her science lesson planning process:

> Inquiry is a huge part of our science instruction as a team. Whenever beginning a new topic in science, we typically do something hands-on with inquiry. For example, when introducing circuits, I simply placed a box with the materials to build a circuit on each table without any directions and simply let the students explore the items. (Samantha's writing prompt, 4/20/2017)

When Samantha described her science instruction implementation, she noted the following:

> Often inquiry is a major component of our science, but it is not in every lesson. However, in every science lesson I try and incorporate some sort of small group activity, which takes up the majority of the lesson time. (Samantha's writing prompt, 4/20/2017)

Inquiry, as well as a variety of teaching methods, characterized Samantha's science instruction, both in the planning and implementation per her report.

The data revealed that Samantha's teaching practices encompassed a variety of teaching methods and the use of inquiry as one of those methods. In the video lesson, the researcher observed that Samantha began her lesson as a whole group and later had students working in smaller groups to complete an activity. The students were provided with materials with little direction, except for the desired outcome. The report of her typical teaching practice, planning, and implementation in her writing prompt was consistent with what she enacted in the lesson video that she submitted.

Inquiry Continuum

Samantha's video lesson was used as evidence regarding the position of her science instruction along the Inquiry Continuum prior to engaging in lesson study. For the first essential feature regarding learner engagement with scientifically oriented questions, instruction was at the more teacher-directed end of the spectrum, as Samantha posed the question or presented the challenge and materials that were necessary to complete the task to the students. Students were also given the opportunity in the lesson to formulate explanations from evidence and connect those explanations to scientific knowledge, both corresponding to essential features three and four, respectively (see Figure 8). For essential feature three, Samantha used a more student-directed approach, in that students were guided in the process of formulating explanations for evidence as Samantha circulated the groups and supported them through the process. Conversely, Samantha took a more teacher-directed approach at the end of the lesson, as she provided some of the possible connections to the students. The video did not show students communicating or justifying their explanations, so the final essential feature did not apply. A summary of how Samantha's lesson fit the spectrum before lesson study can be found in Figure 8.

Essential Feature	Variations			
1. The learner is engaged in scientifically oriented questions.	The learner poses a question.	The learner selects among questions; poses a new question.	The learner sharpens or clarifies a question posed by teacher, materials, or other sources.	The learner engages in questions provided by teacher, materials, or other sources.
Samantha's Instruction				X
3. The learner formulates explanations from evidence.	The learner formulates an explanation after summarizing the evidence.	The learner is guided in the process of formulating explanations from the evidence.	The learner is given possible ways to use evidence to formulate an explanation.	The learner is provided with evidence.
Samantha's Instruction		X		
4. The learner connects evidence to scientific knowledge.	The learner independently examines other resources and forms the links to explanations.	The learner is directed toward areas and sources of scientific knowledge.	The learner given possible connections.	
Samantha's Instruction			X	
	More-----------Amount of Learner Self Direction-----------Less Less--- Amount of Direction from Teacher or Material --- More			

Figure 8. Samantha's practice on the Inquiry Continuum before lesson study.

The Case of Christina Thomas before the Lesson Study

Christina Thomas (Pseudonym) was a Caucasian female who worked as a member of the fourth-grade team at the same elementary school. She had five years of teaching experience at the time of the study. She taught two years in middle school at the seventh-grade level. Christina spent three years at the elementary level: one year as a fifth-grade teacher and two years at the fourth-grade level. The highest degree Christina obtained was a Master of Education, but she mentioned a desire to go back to school to pursue a doctorate in STEM education.

Writing Prompt

When Christina was asked about her science teaching in her classroom, she stated that science content was usually integrated with other subjects. She stated the following concerning a typical science lesson in her classroom:

> Science is in every subject, so when I plan a science lesson, I want to see how I can incorporate other aspects of learning. I will look at the standard and see if it fits with anything off the top of my head in other subjects. If not, I will try to find something to connect the learning objective to. Then I am going to figure out what the end result needs to be . . . what do they really need to know? After I figure that out, I might add activities that are appropriate to reach that goal. Before starting the actual teaching though, I will allow inquiry into the standard I am teaching. (Christina's writing prompt, May 2017)

The response was consistent with that of the other participants, in that they all started with a standard and sought connections to other content areas for the purpose of integration.

Videoed Lesson

Lesson description. Christina submitted a video lesson of her science teaching in her classroom. In the lesson, she built background knowledge so that the students could construct the definition of a system in nature. The lesson was similar to the lesson that Hannah had implemented with her students. The length of footage submitted by Christina consisted of approximately 11 minutes of question-and-answer time with her students. The students were all seated on the floor facing the teacher as she wrote and drew on a mobile whiteboard, in a similar configuration to that in Hannah's class during a similar lesson (see Figure 5).

The video of the lesson began with Christina already engaged in a question-and-answer session with students; she was asking students to define a *system*. Christina sat next to the mobile whiteboard and asked questions, accepting responses until the students provided the definitions and descriptions of the supporting terms of a system. Christina used the example of an aquarium to build the schema of a system for the students. This was the only activity during the lesson. The footage ended when all relevant vocabulary terms were defined and related to a system. Below is a sample excerpt of the transcript of the video lesson.

1-1 Christina: What interactions are going on right now?

1-2 Students: Listening. Talking. Discussing.

1-3 Christina: Listening and talking. Discussing. OK.

1-4 Christina: All right, an interaction is a mutual action or influence. What does it mean to be mutual?

1-5 Student: OK, mutual means if a truck breaks down, you can push it. If it breaks down, you can push it up the ramp for like the tow truck can get it.

1-6 Christina: Tow truck. That's an interesting definition of mutual. If I have a mutual friend with Jaden, what does that mean? If Sarah has somebody that she is going to introduce her to, she becomes a mutual friend.

1-6 Student: They both are in the same space.

1-7 Christina: That’s a hard word to explain. Let’s move on.

All right, what about this word (pointing to a new word on the board)? Interdependence or interdependent (reads the definition) mutually relying on or requiring the aid of another. What of this stuff is interdependent (Motioning to all material that had already been written on the whiteboard)?

1-8 Student: Suckerfish is dependent.

1-9 Christina: On what?

1-10 Student: It’s just a sucking fish is the bigger, but the other fish we saw has (trails off inaudibly).

1-11 Christina: So, it’s dependent on?

1-12 Student: The sucker fish is depending on the algae so he can eat it.

1-13 Christina: Absolutely.

1-14 Student: Could the fish be dependent on the owner because it has to give them food? And the owner may feel lonely.

1-15 Christina: Yes! OK. What else is a product of the interactions that go on in [the fish tank]?

1-16 Student: A clean tank.

1-17 Christina: Yes. A clean tank. Live fish, yes. What else is a product of the interactions that go on in here? What else is an interaction, or what else is an output? (Christina's video lesson transcript, May 2017)

TDOP analysis. When the video began, Christina was writing on the board, asking questions and accepting responses. Because of the configuration of the students' seating arrangement and the constant exchange of dialogue between the teacher and the students, the researcher coded the activity as Socratic lecture as an instructional method. Lecture while writing (LW) was coded for the majority of the intervals, and Socratic lecture (SL) was coded for all of the intervals. The dialogue between the students and the teacher was consistent throughout the course of the lesson. Teacher-led dialogue was the primary type of teacher-student interaction. Instructor display questions (IDQ) or questions requiring a specific answer were coded for 100% of the intervals.

For Christina's lesson, the data indicated that the instruction was largely teacher-focused. For each interval, the primary teaching method was Socratic lecture. The students were positioned in a whole group manner around the whiteboard so as to create the environment for discussion. Christina asked several questions to which the students delivered responses. The majority of the questions were coded as display questions due to the nature of the question and the type of answer being solicited. Questions in the transcript found on lines 1-1, 1-9, 1-14, 1-18, and 1-20 are examples of questions posed in the lesson that the researcher coded as instructor display questions.

The instructional technology dimension was coded continually for whiteboard use, which was the only technology used throughout the extent of the lesson. Christina utilized the whiteboard to draw and write as she asked questions and accepted responses from the students concerning a system. The primary teaching method that Christina used in the lesson was lecturing while writing, coded as LW.

Emphasis on Standards that Integrate into Other Content

Prior to engaging in lesson study, the data suggested that Christina's focus of her science teaching included a variety of teaching methods, but always began with the standards. When asked about her planning process, Christina reported the following:

> Planning a typical science lesson involves more than science. Science is in every subject, so when I plan a science lesson, I want to see how I can incorporate other aspects of learning. I will look at the standard and see if it fits with anything off the top of my head in other subjects. If not, I will try to find something to connect the learning objective to. (Christina's writing prompt, May 2017)

She went on to say that the standards were at the forefront of her planning and her lessons as she described her typical implementation of a science lesson in her classroom. (Christina's writing prompt, May 2017)

In both the planning and implementation portion of her science lessons, Christina cited a variety of teaching methods and activities, but seemed to prefer inquiry in her classroom. She noted the following: "Before starting the actual teaching though, I will allow inquiry into the standard I am teaching" (Christina's writing prompt, May 2017). She stated the following about her implementation:

> Student inquiry is my favorite way to begin any science lesson. So, student participation is at an all-time high. Types of activities vary based on the needs of students to understand the standard. Energy isn't quite as easy to inquire with as

magnets. Magnets, I hand them a bunch of magnets and they inquire. (Christina's writing prompt, May 2017)

The data revealed that Christina's teaching practice displayed an emphasis on always starting with a standard and integration into other content areas. It was also noted that equal significance was placed on beginning a lesson plan or implementation with the standards, and Christina sought to incorporate inquiry into her science teaching practice. The researcher observed that the report of a typical science lesson via the writing prompt was incongruent to the enacted science lesson submitted via video. There was no mention of the standards being addressed in the video lesson. Furthermore, the lesson did not reflect the use of inquiry as described by the writing prompt in a typical lesson.

Inquiry Continuum

Christina's video lesson was also used to determine how her classroom practices were reflected on the Inquiry Continuum. Christina's lesson only aligned with the first essential feature of inquiry per the spectrum in Figure 9. The students engaged in scientifically oriented questions that were posed by the teacher, and in some instances, the learner-posed questions. The majority of the lesson was composed of questions posed by the teacher; thus, the part of the spectrum that aligned most closely to the lesson was toward the more teacher-directed end. Figure 9 summarizes Christina's instructional practice, as compared to the Inquiry Continuum before engaging in the lesson study cycle.

Essential Feature	Variations			
1. The learner is engaged in scientifically oriented questions.	The learner poses a question.	The learner selects among questions; poses a new question.	The learner sharpens or clarifies a question posed by teacher, materials, or other sources.	The learner engages in questions provided by teacher, materials, or other sources.
Christina's Instruction				X
	More-----------Amount of Learner Self Direction-----------Less Less--- Amount of Direction from Teacher or Material --- More			

Figure 9. Christina's practice on the Inquiry Continuum before lesson study.

Cross-Case Analysis

Case descriptions were used to identify trends across the group and summarize differences in teaching practices. The trends were employed to define the teaching practices of the whole case, which included all of the participating teachers or the embedded cases. In this section, first, commonalities between the participants regarding their observed and reported teaching practice emphases are discussed. This is followed by an assessment of how all participants compared on the Inquiry Continuum (NRC, 2000).

Case Commonalities

All participants shared common practices in planning and implementation of science lessons in their individual classrooms. When planning science lessons, all participants began with a state standard as the central focus. Participants reported in the writing prompt that planning usually started with a non-science topic, as another common emphasis was on integrating science within other content areas. All participants also noted that when planning science lessons, this process often occurred as a collaborative endeavor among the fourth-grade team.

Some participants, however, shared commonalities that were not characteristic of the whole group. For example, when reporting on science lesson planning, both Hannah and Samantha mentioned the importance of using nonfiction texts as a central theme of science instruction. Christina did not mention the use of nonfiction texts in her writing prompt when reporting on her science instruction. Additionally, Christina and Samantha shared a common emphasis on using a variety of teaching methods (inquiry in particular) in delivering science instruction. Though not explicitly stated, both Christina and Samantha cited examples of inquiry as giving students tasks with little direction and allowing them to inquire to discover the key elements of the content.

Within the enacted lessons submitted via video from the participants, the common practice observed by the researcher was the use of lecture, either at the beginning of or during the majority of the science lessons. Both Hannah and Christina utilized Socratic lecture and lecture while writing when they were teaching in the video lesson. Samantha began her lesson with a short lecture to introduce the topic for the day, but did not return to a lecture format for the duration of the lesson.

Inquiry Continuum

The use of the Inquiry Continuum (NRC, 2000) allowed the researcher to analyze the teaching practices of each participant based on reform-oriented science teaching standards. Each teacher's video lesson was categorized according to the continuum. There was only one essential feature, number one, on the continuum that all of the participants demonstrated in their science teaching. All participants allowed students the opportunity to engage in scientifically relevant questions and materials which represented Feature 1 on the continuum. All participants' teaching practices were aligned with the teacher-directed end of the spectrum for Feature 1 because questions and the materials provided were generated solely by the teacher and none by the students (see Figure 10).

Essential Feature	Variations			
1. The learner is engaged in scientifically oriented questions.	The learner poses a question.	The learner selects among questions; poses a new question.	The learner sharpens or clarifies a question posed by teacher, materials, or other sources.	The learner engages in questions provided by teacher, materials, or other sources.
All participants				X
	More-----------Amount of Learner Self Direction-----------Less Less--- Amount of Direction from Teacher or Material --- More			

Figure 10. Common teaching practice on the Inquiry Continuum prior to lesson study (NRC, 2000).

Summary

Through an analysis of the case descriptions, commonalities in planning and implementation among the embedded cases were identified. These included beginning planning with a non-science state standard and planning that was collaborative in nature. Other commonalities included an emphasis on using nonfiction texts (shared by Hannah and Samantha) and an emphasis on using inquiry or discovery learning (shared by Samantha and Christina). The group's teaching practice reflected the first essential feature – the learner engaged in scientifically oriented questions, but the instruction was largely teacher-focused. In the next section, the lesson study process is described.

Lesson Study Process

The following is an account of the interactions and experiences of the participants as they engaged in the lesson study process. The narrative includes interactions and experiences beginning with the initial meeting and subsequent planning session, followed by the three phases of the lesson study process: the research lesson, debriefing, and re-teaching the lesson.

Initial Meeting

To begin the lesson study process, the participants met for a planning session to decide what content would be taught for the research lesson portion of the lesson study. The researcher shared some norms and practices that would guide the planning session, as well as the role of the researcher for the planning session; then, the audio recording began. After which, the researcher became a passive observer of the planning session and collected fieldnotes of the interactions and group dynamics.

The meeting took place early in the morning before the start of school. Each participant had a scheduling conflict, which prevented the group from meeting at a later time. Samantha and Hannah were scheduled to leave for the day to attend a professional development session being offered at the district office in preparation for the upcoming school year. Christina was the only teacher who would be in the building that day, and she was working on an end-of-the-year project.

Rosy, the knowledgeable other, began the meeting by asking the group what standards should be retaught from the previous curriculum. They decided on the energy standard, and Hannah suggested looking at the state performance indicators in science to begin the conversation about what to teach for the research lesson. Christina confirmed that it was a standard that would be used in fifth grade as well. Rosy suggested that the group's plan center around clearing up misconceptions that may have been embedded by going deeper into the fourth-grade standard without going too far into the fifth-grade standard. Samantha nodded in agreement. Figure 11 shows two of the fourth-grade state science standards for Energy.

Standards:

Design an investigation to demonstrate how different forms of energy release heat or light.

Design an experiment to investigate how different surfaces determine if light is reflected, refracted, or absorbed

Figure 11. State Science Standards for energy in the fourth grade.

Hannah, Rosy, and Christina were the dominant contributors to the conversations as they settled on the specific topic to be taught. The conversation proceeded as follows:

1-1 Rosy: Let me ask you a question; when you do that investigation, look at your other standards because you are going to be synthesizing because they have already mastered these as an understanding. So how can you combine those with others that they know so that they can get to that synthesizing phase for them to synthesize information?

1-2 Hannah: I think that they are all very intertwined because the second one says that you are designing experiments and how different services determine if light is reflected refracted or absorbed. If you are looking for light energy in the first one, I think that (clears throat) it covers them all.

1-3 Christina: See, I think that it's either. I disagree. To me, it's almost like they don't match at all because it doesn't talk about (Pause)

1-4 Hannah: (Interrupting Christina's thought) I think that when we are actually doing it they will overlap because…

1-5 Christina: I don't think that is what they are asking for because of the light component.

1-6 Hannah: ...All of their wording is very screwy.

1-7 Rosy: Well, theirs is isolated.

1-8 Christina: It's absolutely completely isolated. I don't feel like there is any intertwining between it, but we can make it intertwine.

1-9 Hannah: But when we do it, it will intertwine with the light component of it.

1-10 Rosy: Because where is this in the real world, what's the 'So what'? Why do they have to know this standard? What's the 'so what'?

1-11 Hannah: My mind automatically goes to like solar power, solar … those kinds of things.

1-12 Christina: The absorption of the light from the sun to the solar panels. I think about even just basic life with them, like why would I not wear a black shirt in July? Why would I want to wear a white shirt in the middle of July? I mean just being a human.

1-13 Hannah: An experiment, an investigation could be cooking with aluminum foil boxes…

1-14 Christina (Interrupts): The solar panel.

1-15 Hannah: We talked about doing that. That would be, that would be so fun because that transfers the sun's energy into heat energy to cook your s'mores or whatever little thing you are cooking.

1-16 Samantha: (Affirmative response).

1-17 Rosy: So, is that what you are thinking that you will do for this investigation?

1-18 Christina: Well, we had planned on doing that at the end of the year. So, if we want to do this on Friday, I think that we might need to do something to build up to that so, and still do that. As far as the end-of-the-year project, we can use some of this stuff to do. They can investigate the refraction and reflection.

(Lesson planning transcript, 5/02/2017)

Hannah suggested an investigation on energy because "we have not done any investigation or inquiry in my room as far as energy goes" (Lesson planning transcript, 5/02/2017). The conversation around what to teach culminated with Hannah suggesting the use of the greenhouse located at the backside of the school building and planning an experiment or investigation of solar energy being transferred into heat energy. Rosy asked if the participants had taught the students how to truly do investigations. Hannah confessed that she did not do a good job of [investigations], and she was planning to start the next year with explicit instructions on how to conduct a scientific investigation and the necessary elements so that she and her students could continue the conversation all year long. She said, "That's on my list for the beginning of the year just to unroll that just right off so that we do more investigating so instead of teaching that in with every standard, I want to teach that upfront" (Lesson planning transcript, 5/02/2017). Samantha agreed that a lack of investigating and inquiry was true of her class as well. Christina agreed that she did not do many investigations in her class either, but she did try to focus on an inquiry approach in her classroom science lessons.

Rosy posed the question again of what specific things the participants wanted students to walk away with, to which Hannah responded, "I want them to know that heat energy. . . I want them to know that different forms of energy release heat or light" (Lesson planning transcript, 5/22/2017). In response, Rosy asked the group how they were planning to get students to that point. Hannah's response reaffirmed her comfort level in how she liked to teach science concepts through articles. She stated, "I always go to reading. I always go to articles. I always think, 'OK, I'm reading articles on solar energy and solar panels'" (Lesson planning transcript, 5/02/2017).

Hannah and Christina offered real-world application ideas until Rosy asked the group how they wanted to teach the lesson. Hannah and Christina spoke about a project that they had wanted to complete in their classrooms that involved cooking with solar ovens, but neither of them was ready to start that portion of the project. Rosy asked the participants what they had outside of the building and on the campus that they could use to write an investigation. Both Christina and Hannah agreed that the greenhouse would be a good site to conduct an investigation. Hannah suggested more real-world applications to a project that the students in her class had been working on. She suggested a video and "maybe another article to gel it all together."

Before the meeting concluded, the group decided that Hannah should be the first to teach the research lesson and be recorded. She agreed and requested help in crafting how the lesson implementation would be executed. Rosy inquired about the process of building more background knowledge in the students, and the participants assured her that connections to content on which the students had worked would be made prior to the research lesson. Hannah continued to brainstorm about the lesson structure with the group, as the lesson would be taught at the end of that week. As the meeting ended, Hannah told the group that she would do more research, type up a lesson plan, and send it to the group before teaching the lesson on Friday. The group agreed and dispersed.

Research Lesson 1

Hannah was the first to teach the research lesson. She sent a copy of the nonfiction text that she had chosen and the lesson that she had prepared to the group prior to teaching the lesson. When selecting the text, she mentioned that she noted the Lexile level, but she was not concerned about it being advanced because she read the article with the students prior to beginning the research lesson. The lesson plan included the agreed-upon standards to be taught and a general overview of what the teacher would say to generate discussion with the students. Once the substitute teachers were set up in the other classes, everyone met in Hannah’s classroom to begin the lesson. The students were quietly waiting for the lesson to begin but were a little distracted by the camera and the visitors.

Hannah asked the students to gather their notebooks and line up, as the beginning of the lesson would take place in the foyer leading outside to the greenhouse. Once in the foyer, the students were seated much like in the science lesson that was previously submitted. Hannah began her lesson with a disclaimer about how the lesson was not intended to teach whether global warming was happening or not, but to analyze the terminology using the available resources. She began the lesson by stating, “Yesterday we had a really good discussion about what we knew about heat and energy related to our article, and today we are going to continue to explore that using our greenhouse” (Research Lesson 1 video, 5/12/2017). This statement reminded the students that this part of the lesson was a continuation of the previous science lesson using the article for context. To review, the students were asked questions about previous connections that they made, and then they exited the building.

Once outside, the students were instructed to get into their partner groups to prepare to enter the greenhouse to collect data. Once in the greenhouse, Hannah gave more instructions and asked more questions to assess knowledge and collect inferences that the students might be making about the greenhouse. The students collected their data in the chart included in the student pages of the packet and exited the greenhouse (see Figure 12).

Current weather Temperature / humidity / wind	Current greenhouse conditions Temperature/ humidity/ wind	Observations

Figure 12. Data collection chart created by Hannah for greenhouse data collection.

Upon exiting the greenhouse, the students were instructed to sit on the sidewalk in their partner groups, and Hannah led a debriefing where the students had the opportunity to discuss connections from the data collected in the greenhouse to the nonfiction text (Sumner, 2016) that had been previously read. The discussion began as follows:

1-1 Hannah: All right, all right, I want you to turn and talk to your partner using the thinking stems on your second page. OK, you are still in an area where you can make some more observations about the outside of the greenhouse. So what space would we be in now if the greenhouse is our atmosphere? Where are we now?

1-2 Student: Outer space

1-3 Hannah: In outer space. OK, so is there a difference between the inside of the greenhouse and the outside of the greenhouse?

1-4 Students: Yes.

1-5 Hannah: There is an observable difference, with and without scientific tools. Discuss with your partner using the thinking stems on your second page. (Looking down at the student's packet) Some of those thinking stems are, I see a pattern in the blank. You guys discussed three distinct patterns while we were in the greenhouse. You said if the blank happened, this other thing would happen. You made a prediction based on patterns. That's an example. Turn and talk to your partner about some other patterns that you could observe. And discuss back to our focus question. Is this an accurate scientific way for scientists to describe the phenomena?

Students were then instructed to complete their connections chart (Figure 13), also included in the student pages of the packet that corresponded to the lesson plan. The column labeled *Article* was intended for students to record thoughts from the reading provided earlier. The column labeled *Scientific* was intended for students to record connections made from the data collection in the greenhouse to thoughts from the reading that had been previously read.

Connections

Article	Scientific
Other	

Figure 13. Connections chart created by Hannah where the students would record connections made between the article that the students read and the data they collected in the greenhouse.

As the students discussed in their partner groups and completed their connections chart, Hannah circulated among the students, checking in and asking probing questions to help guide their thinking and to stay on task. She noticed that several students had left a large portion of their connections chart blank, particularly in the article section, so she brought the students back to the whole group to discuss the article connections further.

1-6 Hannah: All right, who would like to share your response that you and your partner had to that question?

Following a brief silence. [Student] tell me what you and [Student's partner] decided.

1-7 Student: (Inaudible)

1-8 Hannah: OK, tell me what you're thinking is.

1-9 Student: (Inaudible)

1-10 Hannah: OK.

1-11 Student: (Inaudible elaboration)

1-12 Hannah: Ah! So, you're wondering could the amount of gases in our atmosphere form a barrier like that. OK. I think that that is a valid researchable question. OK (Calls on another student).

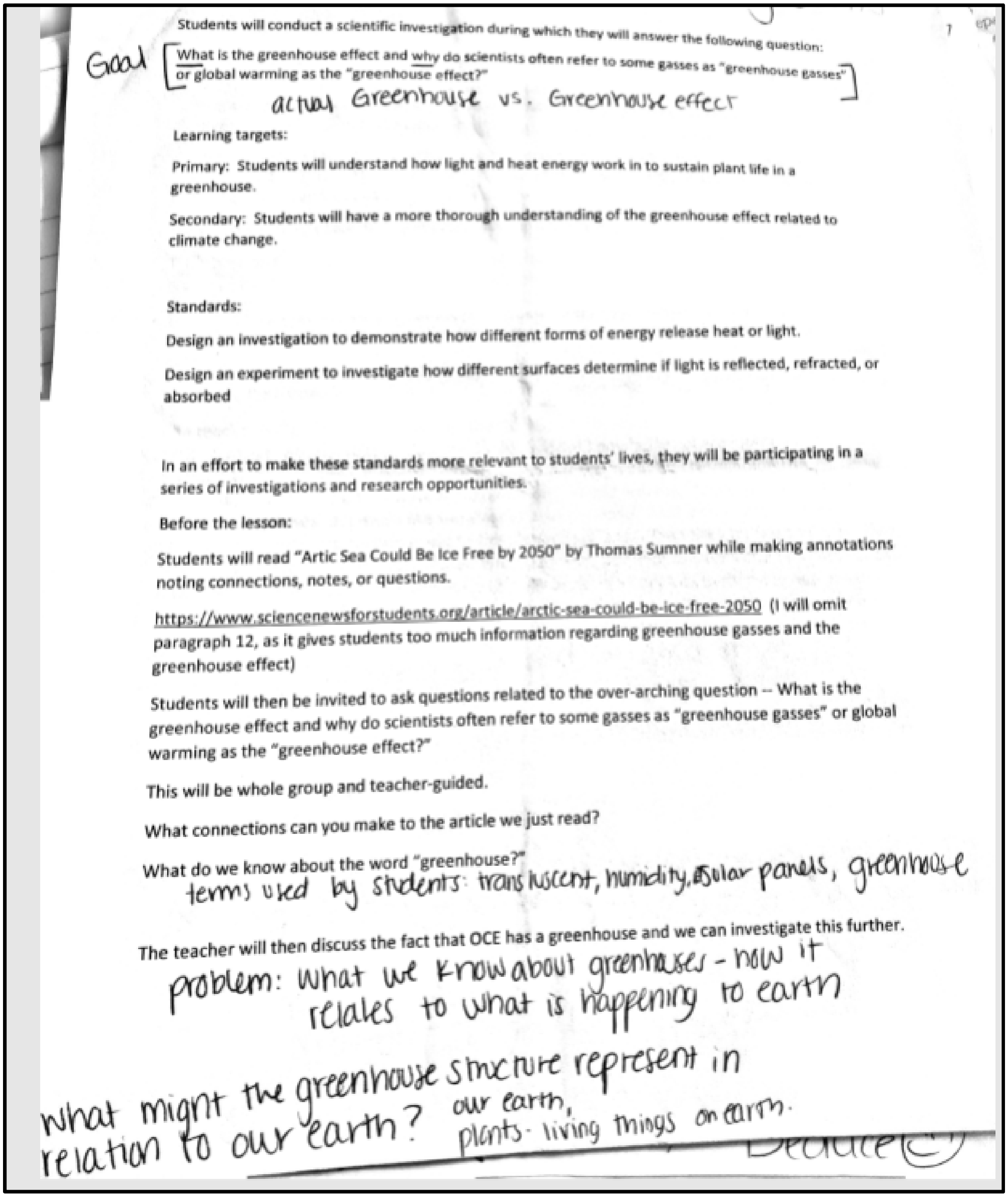
1-13 Student: (Inaudible response)

1-14 Hannah: OK, so they're citing the humidity inside the greenhouse making this an accurate statement. Who has something to build on to that?

Class time was ending, so Hannah instructed the students to put their data tables into their STEAM notebooks and return to the classroom. The entire lesson lasted approximately 35 minutes.

Research Lesson Data Collection

Samantha was an observer and data collector for the first research lesson. Each data-collecting participant was given a copy of the lesson plan, the accompanying nonfiction text, and the student pages on which to take fieldnotes and collect data. Samantha recorded the notes and collected data around teacher action on the documents that had been created by Hannah and that were provided at the beginning of the research lesson. She began by annotating the standard and learning targets. She also made note of the key terms, specific questions that Hannah asked the students, possible follow-up questions, and possible answers. She made mention of a question that Hannah had asked and notated the use of think time (see Figure 14).



Students will conduct a scientific investigation during which they will answer the following question:

Goal [What is the greenhouse effect and why do scientists often refer to some gasses as "greenhouse gasses" or global warming as the "greenhouse effect?"]

actual Greenhouse vs. Greenhouse effect

Learning targets:

Primary: Students will understand how light and heat energy work in to sustain plant life in a greenhouse.

Secondary: Students will have a more thorough understanding of the greenhouse effect related to climate change.

Standards:

Design an investigation to demonstrate how different forms of energy release heat or light.

Design an experiment to investigate how different surfaces determine if light is reflected, refracted, or absorbed

In an effort to make these standards more relevant to students' lives, they will be participating in a series of investigations and research opportunities.

Before the lesson:

Students will read "Artic Sea Could Be Ice Free by 2050" by Thomas Sumner while making annotations noting connections, notes, or questions.

https://www.sciencenewsforstudents.org/article/arctic-sea-could-be-ice-free-2050 (I will omit paragraph 12, as it gives students too much information regarding greenhouse gasses and the greenhouse effect)

Students will then be invited to ask questions related to the over-arching question -- What is the greenhouse effect and why do scientists often refer to some gasses as "greenhouse gasses" or global warming as the "greenhouse effect?"

This will be whole group and teacher-guided.

What connections can you make to the article we just read?

What do we know about the word "greenhouse?"

terms used by students: translucent, humidity, solar panels, greenhouse

The teacher will then discuss the fact that OCE has a greenhouse and we can investigate this further.

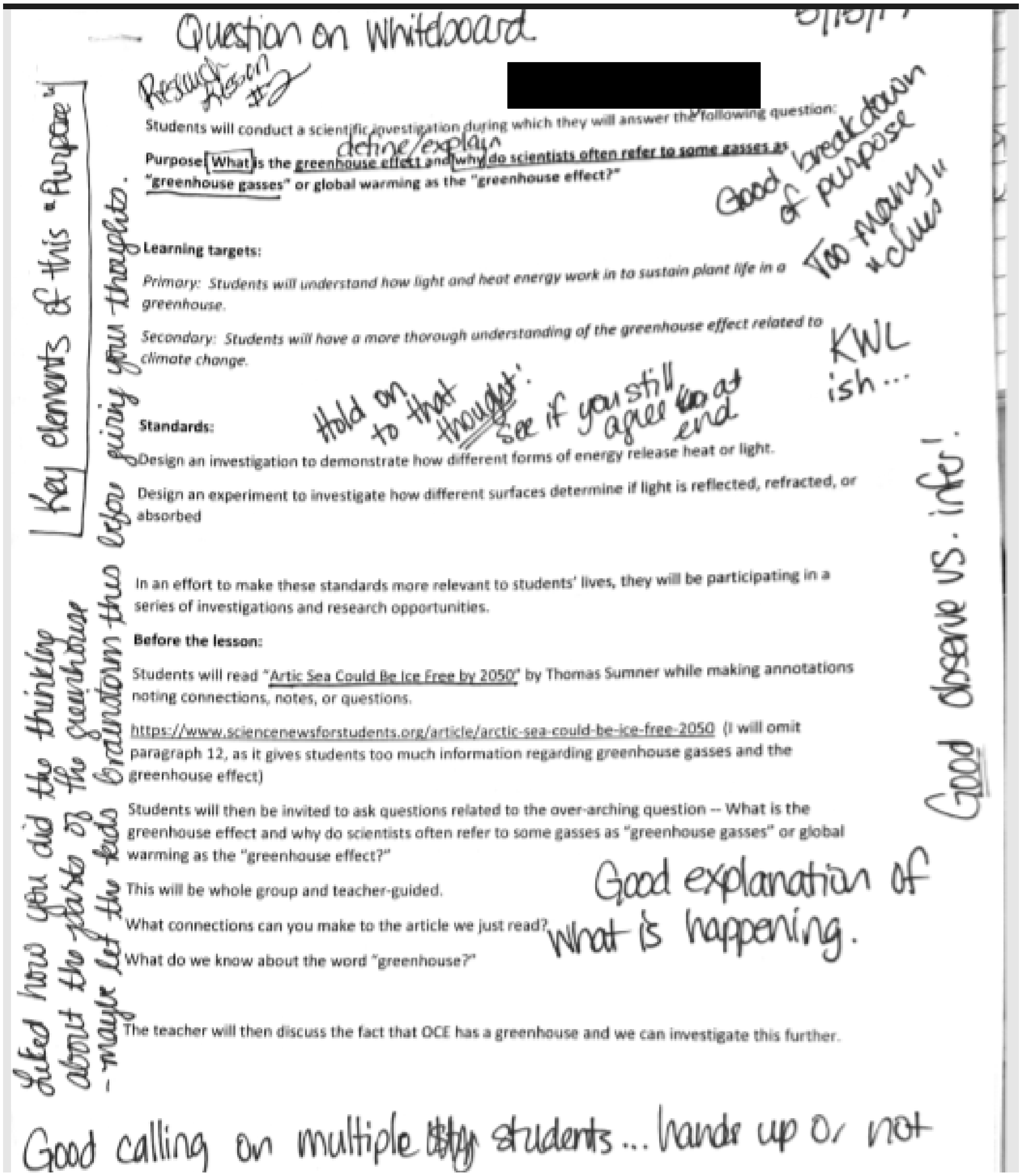
problem: What we know about greenhouses - how it relates to what is happening to earth

What might the greenhouse structure represent in relation to our earth? our earth, plants - living things on earth.

Figure 14. Sample of Samantha's data collection in the research lesson.

During the lesson, students seemed confused about the observations and inferences when talking about the greenhouse. Samantha made a note on the lesson plan. Samantha noted that Hannah reviewed scientific tools in the lesson and made use of scientific terms, as well as utilized Tier II words that students had learned at the beginning of the school year. Tier II words are high frequency vocabulary words that have multiple meanings across content areas. Once the students left the greenhouse and sat on the sidewalk to discuss and analyze their observations, Samantha circulated to hear these conversations and note what was being written. However, she did not record any observations on the student pages for data collection. Samantha's focus appeared to be dedicated more to teacher moves than student outcomes.

In addition to Samantha, Christina also served as an observer and data collector for the first research lesson. Christina began collecting data on the teacher and made some comments about the students, but the majority of her data collection focused on teacher moves and dialogue. She began by making note of the questions and phrases made by Hannah that she felt were notable (see Figure 15). Next, she continued her data collection on the student data charts of the provided lesson plan and student pages. Her comments included a mixture of edits to be made to the document provided by the teacher to the students, as well as some assessment regarding the quality of the questions asked to the students (see Figure 16).



Question on whiteboard

Research Lesson #2

[redacted]

Students will conduct a scientific investigation during which they will answer the following question:

define/explain

Purpose: What is the greenhouse effect and why do scientists often refer to some gasses as "greenhouse gasses" or global warming as the "greenhouse effect?"

Good breakdown of purpose

Too many "clues"

Learning targets:

Primary: Students will understand how light and heat energy work in to sustain plant life in a greenhouse.

Secondary: Students will have a more thorough understanding of the greenhouse effect related to climate change.

KWL ish...

Standards:

Hold on to that thought! See if you still agree at end

Design an investigation to demonstrate how different forms of energy release heat or light.

Design an experiment to investigate how different surfaces determine if light is reflected, refracted, or absorbed

In an effort to make these standards more relevant to students' lives, they will be participating in a series of investigations and research opportunities.

Before the lesson:

Students will read "Artic Sea Could Be Ice Free by 2050" by Thomas Sumner while making annotations noting connections, notes, or questions.

https://www.sciencenewsforstudents.org/article/arctic-sea-could-be-ice-free-2050 (I will omit paragraph 12, as it gives students too much information regarding greenhouse gasses and the greenhouse effect)

Students will then be invited to ask questions related to the over-arching question -- What is the greenhouse effect and why do scientists often refer to some gasses as "greenhouse gasses" or global warming as the "greenhouse effect?"

This will be whole group and teacher-guided.

What connections can you make to the article we just read?

What do we know about the word "greenhouse?"

Good explanation of what is happening.

The teacher will then discuss the fact that OCE has a greenhouse and we can investigate this further.

Key elements of this "Purpose"

before giving your thoughts. Brainstorm thus

Liked how you did the thinking about the parts of the greenhouse - maybe let the kids

Good observe vs. infer!

Good calling on multiple students... hands up or not

Figure 15: Excerpt of the first page of Christina's data collection of the research lesson.

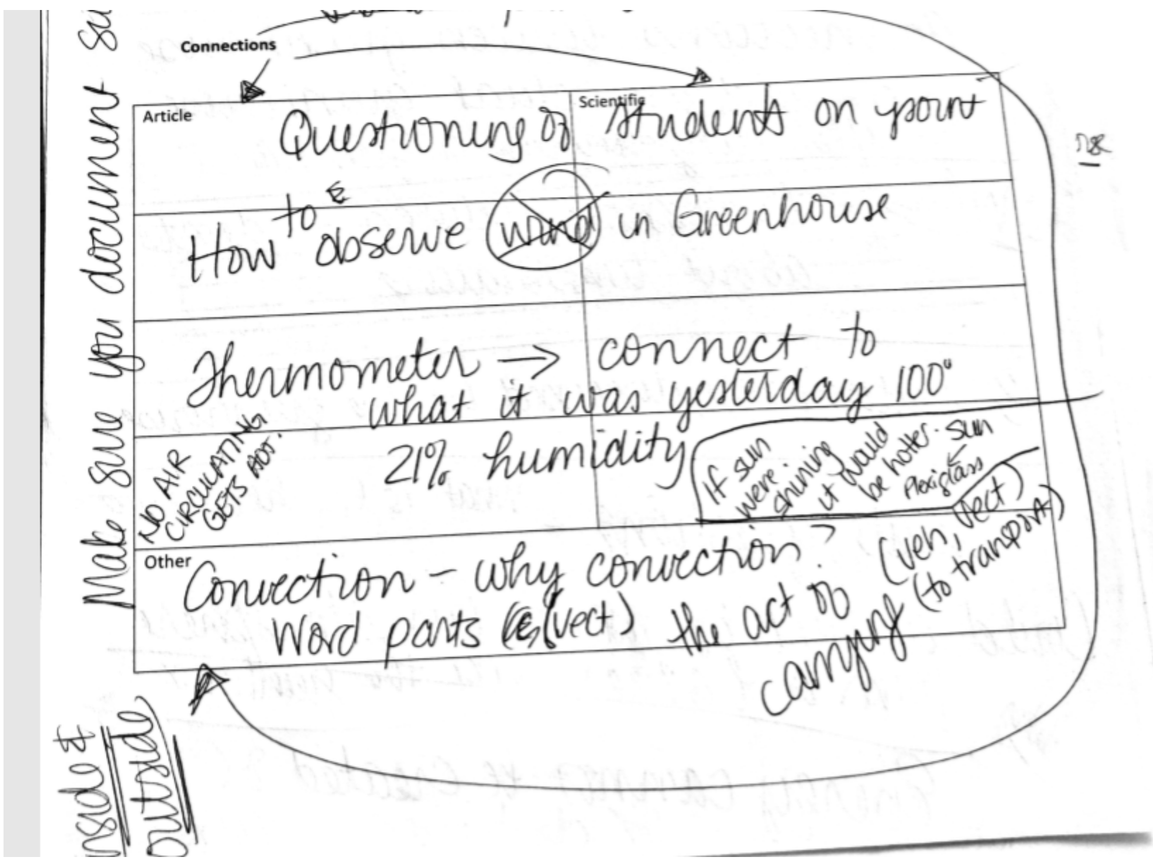
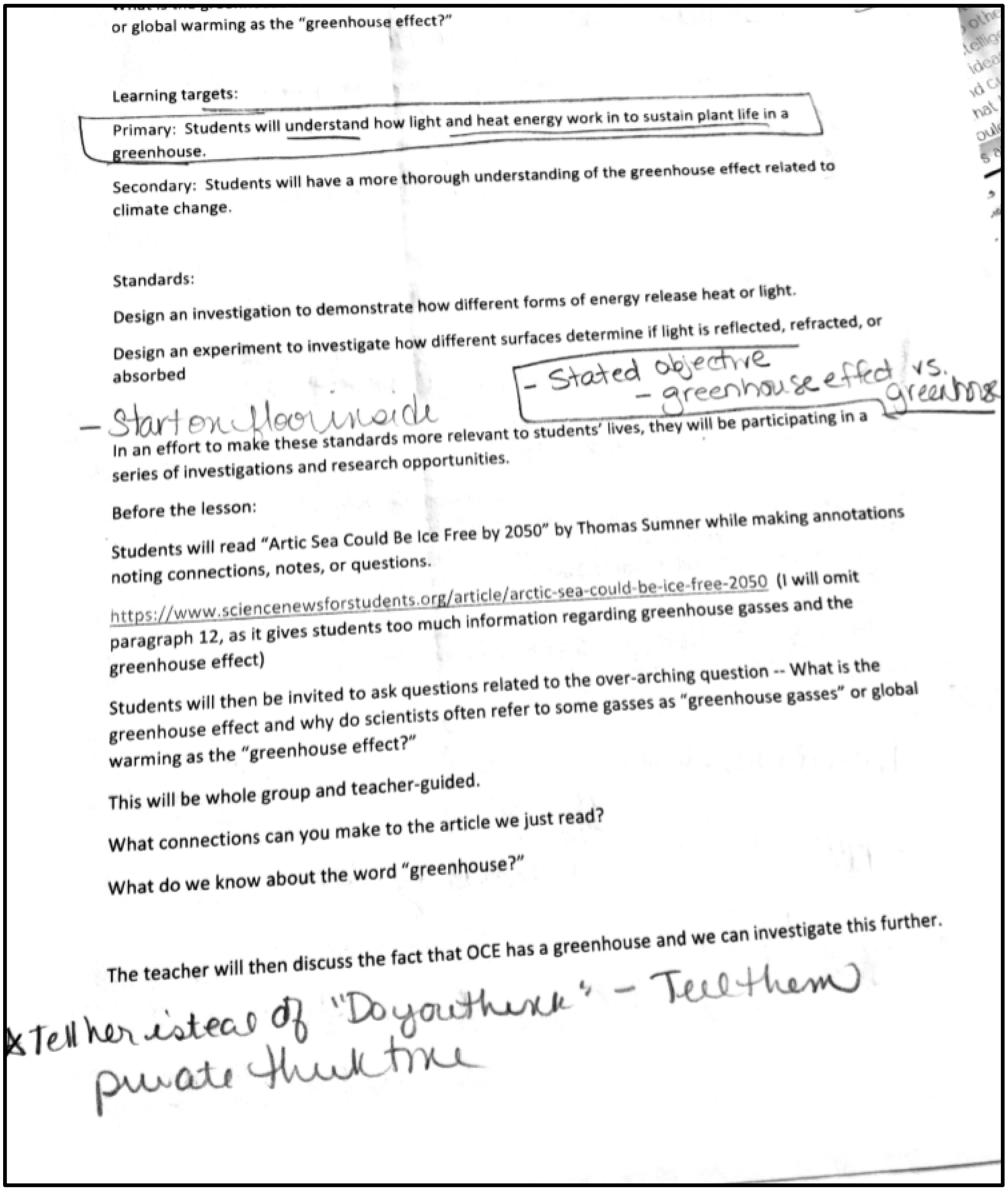


Figure 16. Christina's data collection during the research lesson on a student's page.

Rosy was also present at the research lesson, and she collected data. She made note of every aspect of the teaching process during this lesson. She began by annotating the lesson plan by marking the learning targets and making note that Hannah stated the objective to the students. She also made notes about how the practices could be adjusted by adding in think time following a question. On the backs of the lesson plan pages, Rosy wrote out the sequence in which Hannah proceeded in the lesson, questions asked of the students, and suggestions for deeper questioning and comprehension. She then annotated the student pages by making suggestions to the structure in order to add clarity for the students. Examples of Rosy's data collection can be found in Figures 17, 18, and 19.

Prior to the end of the lesson, Rosy received a call that her daughter was sick, so she had to leave for the day. She left her notes with the researcher and asked if they could be shared in the debriefing session.



or global warming as the "greenhouse effect?"

Learning targets:

Primary: Students will understand how light and heat energy work in to sustain plant life in a greenhouse.

Secondary: Students will have a more thorough understanding of the greenhouse effect related to climate change.

Standards:

Design an investigation to demonstrate how different forms of energy release heat or light.

Design an experiment to investigate how different surfaces determine if light is reflected, refracted, or absorbed

- Stated objective
- greenhouse effect vs. greenhouse

- Start on floor inside

In an effort to make these standards more relevant to students' lives, they will be participating in a series of investigations and research opportunities.

Before the lesson:

Students will read "Artic Sea Could Be Ice Free by 2050" by Thomas Sumner while making annotations noting connections, notes, or questions.

https://www.sciencenewsforstudents.org/article/arctic-sea-could-be-ice-free-2050 (I will omit paragraph 12, as it gives students too much information regarding greenhouse gasses and the greenhouse effect)

Students will then be invited to ask questions related to the over-arching question -- What is the greenhouse effect and why do scientists often refer to some gasses as "greenhouse gasses" or global warming as the "greenhouse effect?"

This will be whole group and teacher-guided.

What connections can you make to the article we just read?

What do we know about the word "greenhouse?"

The teacher will then discuss the fact that OCE has a greenhouse and we can investigate this further.

*Tell her instead of "Do you think" – Tell them private think time

Figure 17. Rosy's annotation of Hannah's lesson plan.

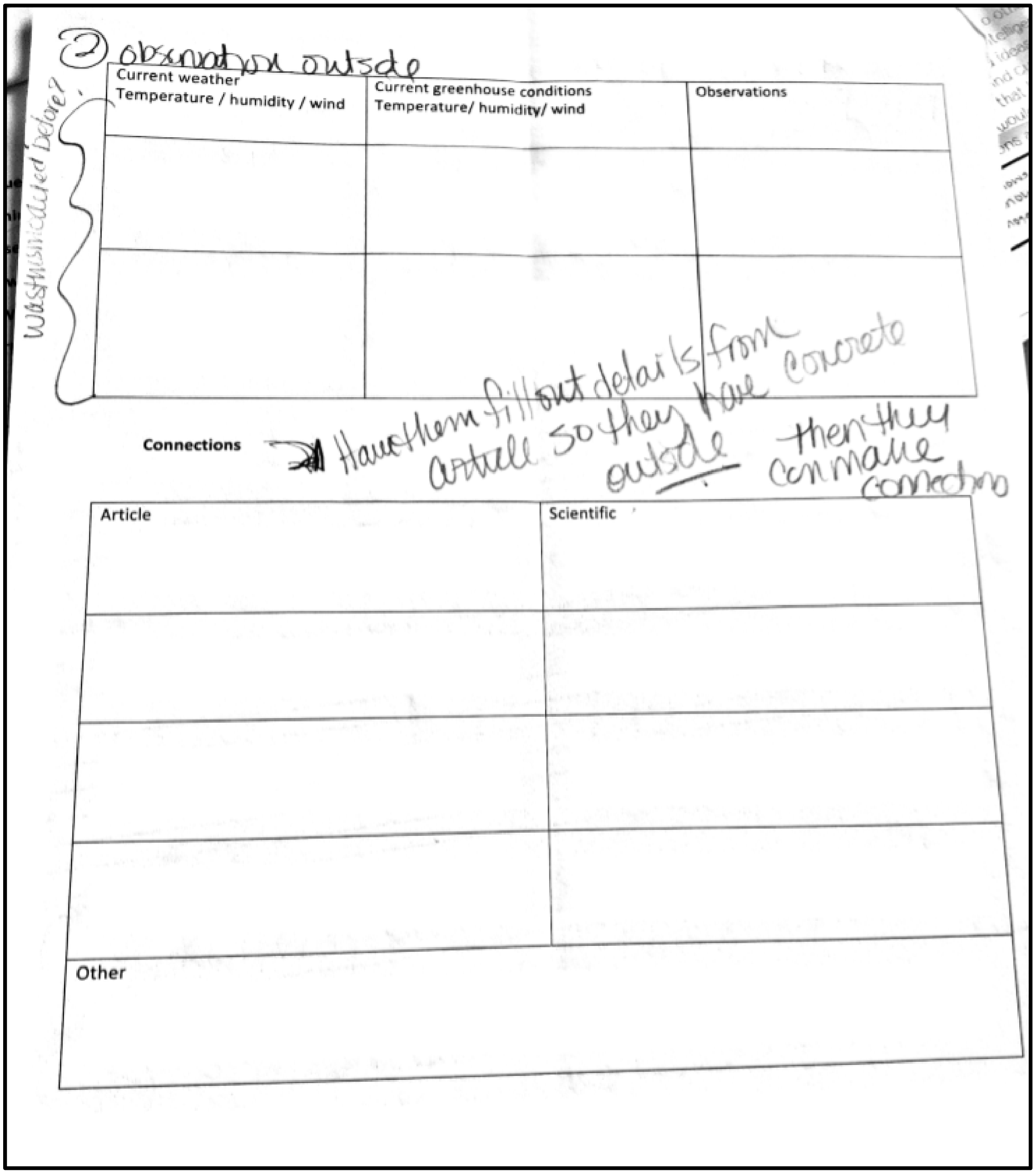


Figure 18. Rosy's annotation of the student pages.

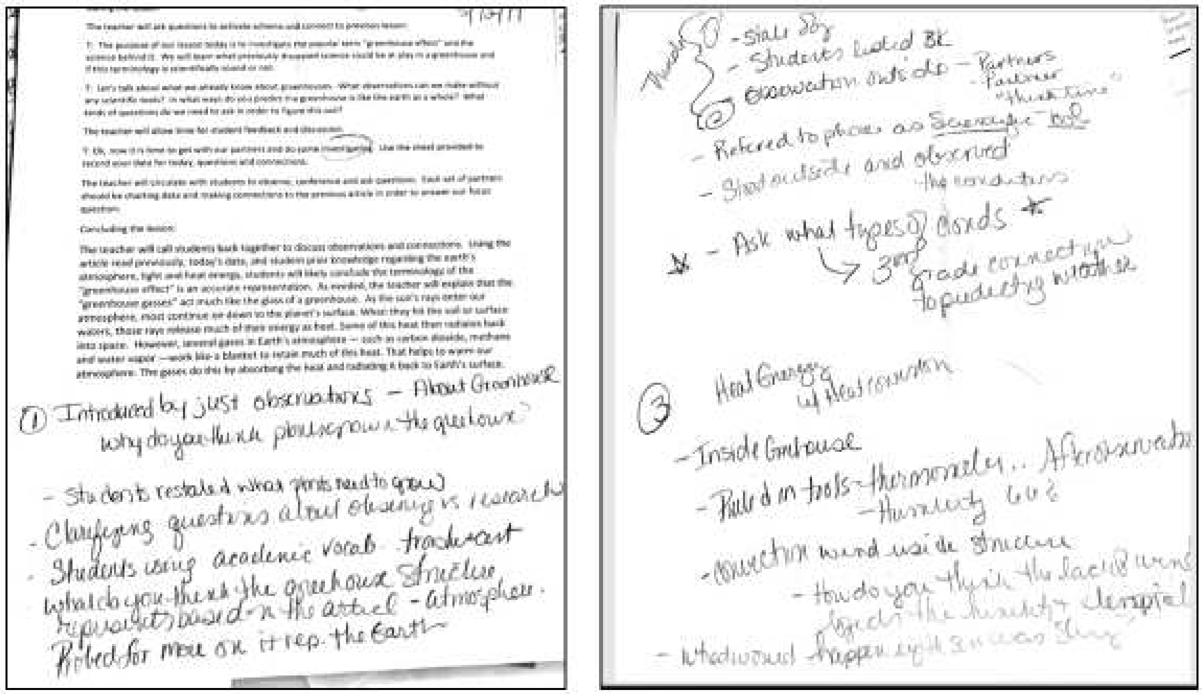


Figure 19. Rosy's observations from Hannah's lesson.

Research Lesson 1 Debrief

The participants elected to debrief immediately following the teaching of the first research lesson. Once the students were dismissed, the researcher and the group met in the classroom to debrief. The session was originally scheduled to be facilitated by Rosy, but she was absent due to a family emergency. Christina filled in as a facilitator by presenting the data that Rosy collected to the group. This allowed the researcher to maintain the role of non-participant observer. Before the beginning of the debrief session, the researcher shared the group norms.

Hannah, the lesson instructor, shared her reflection of the lesson first. Hannah mentioned that the lesson in her opinion had some disappointing moments and some moments of success. She stated that she was disappointed in the lack of engagement from the students (Research lesson 1 debrief, 5/12/2017). She felt that the lack of engagement with the lesson might be due to the time of day or the time of year. Hannah also mentioned that she would like to have been "more prepared for higher-level discussion from her higher students" (Research lesson 1 debrief, 5/12/2017), and she would like to do more research on some of the topics that the students brought up to be better prepared. This statement led the researcher to believe that Hannah's disappointment stemmed from a lack of content knowledge necessary to drive meaningful discussion around the science-related topics that emerged in the lesson.

Hannah also shared ideas about the part of the lesson in which she felt the most success. She stated, "I am very pleased with some of the connections that some of them made and some of the questions that they asked." This statement was referring to a question that a student asked about gasses making a barrier. Hannah also expressed disappointment in the students' misunderstanding of the provided sentence stems on the student handout (see Figure 20). There were lines provided on the handout for the students to record their thoughts using the sentence starters, but some of the students did not use the lines at all. She stated, "I was disappointed that some of them, not all of them, used it like a fill in the blank . . . some of them actually asked me what the lines are for. Seriously? That's where you write!" (Research lesson 1 debrief, 5/12/2017).

Questions to further my understanding:

Thinking stems (Kaplan's)

I see a pattern in ________. Why does this occur?

I wonder if this pattern would continue over time?

What if _______ happened? How would _____ change?

The details in the article state _______________. How does _______________?

Figure 20. Sentence stem portions of the student handout.

Hannah mentioned that the students had used the sentence stems previously in class earlier in the school year, so she expected that they would know the purpose of including them in the handout. She seemed to have more thoughts to share about the aspects of the lesson that were less pleasing to her than those aspects that she thought went well.

Once Hannah had shared her evaluation of the lesson, the other participants provided feedback. Christina was the first observer and data collector to share following Hannah's reflection of the lesson. Here the comments were complimentary and validating. She stated the following:

> I love that they had them to move around and I think moving around makes them to be more engaged, which they did perk up a little bit once they were moving…

> That was neat, it was fun. I love watching other people teach. I loved your ‘whys’. I loved when you talked about the ‘whys’ and that you were aware of how many patterns that they saw. And I like the question that you had, and I loved that you had the question stems because I have some kids that can't make the connections. (Research lesson 1 debrief, 5/12/2017)

All of Christina’s initial comments focused on Hannah’s teaching and seemed to address all of the comments about the lesson in which Hannah expressed disappointment. She also offered this validating comment in response to Hannah’s reflection on the students’ lack of engagement:

> I think what you said was very on point. It was almost exactly what I was going to say. I felt like they were disengaged. I totally agree with you that it was the time of day and it’s not a lack of students’ engagement for the lesson. The lesson was totally engaging. (Research lesson 1 debrief, 5/12/2017)

Christina also offered some constructive feedback for the lesson. She noticed that at one point in the lesson, Hannah asked the students to make observations and inferences, and the students seemed confused about the difference between the two. Christina offered the following as feedback:

> I was noticing that they don’t necessarily know the difference between an observation and an inference. It is one of those things that needs to be clarified with kids that an observation is one of those things that you can see, feel, touch, and taste. (Research lesson 1 debrief, 5/12/2017)

Her feedback also included advice about vocabulary clarification and the use of etymology for further explanation.

Samantha was the second data collector to share reflections on the research lesson. She shared complimentary remarks that were reflected in her notetaking. She mentioned, “I liked how you were tying other scientific terms that don't necessarily go with, you know, the greenhouse, like opaque and transparent. And [I like] how you were reviewing the scientific tools and tying all that in together” (Research lesson 1 debrief transcript, 5/12/2017). She referenced this and stated previously during the debriefing session that she did not do this well in her class. She also noted Hannah’s use of Tier II, high frequency vocabulary words that have multiple meanings across content areas, as compared to her use of them in her classroom. The use of vocabulary was the second noted comparison that Samantha made between her class and the classes of the other participants. Samantha closed her feedback by sharing that she noticed from Hannah’s teaching that she needs to work on her use of vocabulary for her students, and she complimented Hannah on the job that she did in the lesson. Samantha did not offer any constructive feedback at this time and did not share any other time during the debrief session.

Once each participant had shared her feedback on the lesson, a follow-up conversation began within the group:

> 1-26 Hannah: So, I’m thinking next year this is one of the class jobs. Go to the greenhouse, check the temperature, check the weather outside, let’s chart it.
>
> 1-27 Christina: I agree. It also ties in, right in with the text pictures where they can actually re-chart the graph, which is important to know how to do.
>
> 1-28 Hannah: And then you will have the ones who read a chart or graph. They could create a chart and graph.

1-29 Christina: Yeah.

1-30 Hannah: Then the others have to read and compare.

1-31: Christina: Totally agree.

1-32 Hannah: I think that next year I would like to use a very similar investigation that is over a period of time so that this happens over.

1-33 Christina: I think that doing it like this, it's hard to make connections to patterns because they expect patterns to be over a long period of time. I would agree. It was a good lesson. I really like it. (Research lesson debriefing session, May 2017)

Hannah pointed out things that she would like to improve upon if there was more time or things that could be used in her science curriculum next year. At the conclusion of this conversation, Hannah requested feedback provided in Rosy's notes. Christina read what was written on the notes and concluded that Rosy's comments were closely aligned to the ones previously shared by her, Samantha, and Hannah. As Christina shared, she directed the feedback toward Samantha, who would be reteaching the research lesson. The comments were as follows:

1-40 Christina: She wrote some notes for you, OK. Ask more questions and have the students ask questions. This will drive the students to answer their own questions based on the articles in partners.

1-41 Hannah: (To Samantha) You can switch the parts on the lesson where they are asking questions first before they go outside.

1-42 Christina: She said maybe move back inside to reflect the change of environment. Be more specific based upon decisions; they were a little too abstract at first. Kind of go over the questions first, so kind of going with the questions first. It might help them to draw more concrete. And I think it might be possible even...when are you (Samantha) teaching the lesson? Even if it was just a couple of days before you could track the data.

1-43 Samantha: Yeah, ummm.

1-44 Hannah: You or a student, I don't know, you just want to have more to pull from that might help with their depth of things as well.

1-45 Samantha: Right.

1-46 Hannah: Since part of the lesson takes place in the greenhouse, that's a little bit harder or this could just be considered a jumping off point. We will continue to track the data.

1-47 Christina: Especially since we haven't had much time.

1-48 Christina: Have them fill out details from the article already, have that already done so that we have that done while they are filling the article out so that we have concrete outside, so that it is easier to make the connections, and I noticed that they did have their article with them, but I agree that if I were to do it again.

1-49 Hannah: All right, so what do you think needs to be done differently for her (Samantha's) lesson, knowing also that her students are significantly different? That's why I think that you (Samantha) need to take the lesson and make the changes that we have talked about, like maybe rearranging the things, maybe changing your thinking stems for them.

1-50 Christina: She may even need to have some of them filled in for some of her students because some of them are significantly lower.

1-51 Hannah: (To Samantha) I'm not sure about the Lexile level on the article. I did read it with the class, so I wasn't concerned, so I wasn't concerned about the Lexile level. (Research lesson debriefing session, May 2017)

After Christina read each of Rosie's comments, she and Hannah continued with suggestions to be implemented in the next lesson. Samantha took note of all advice that was offered. The research lesson took place on Friday, and the group decided to reteach the lesson on the following Monday. The question posed to Samantha by the other participants was whether she would be able to make all of the suggested edits and be prepared to teach the lesson on Monday. She replied in the affirmative and the meeting was dismissed.

Research Lesson 2

On the morning of research lesson 2, Samantha sent an email to the researcher and the participants with attachments to the amended lesson plan, the nonfiction text, which was the same as in the research lesson, and the amended student pages. The lesson plan was adjusted to account for adding in a review lesson on observation and inferences (see Figure 21), and the student pages were adjusted to account for the additional columns and headings in the data charts to add clarity for students' anticipated outcomes (see Figures 22 and 23). These forms were to be used for data collection during the retaught lesson by the observing participants.

During the lesson:

The teacher will ask questions to activate schema and connect to previous lesson.

T: The purpose of our lesson today is to investigate the popular term "greenhouse effect" and the science behind it. We will learn what previously discussed science could be at play in a greenhouse and if this terminology is scientifically sound or not.

T: Let's talk about what we already know about greenhouses. What observations can we make without any scientific tools? In what ways do you predict the greenhouse is like the earth as a whole? What kinds of questions do we need to ask in order to figure this out?

Draw and label a greenhouse in relation to the earth (5min) What do the plants represent, etc.

Review Observation vs. Inference

The teacher will allow time for student feedback and discussion, and then write answers on a chart on the board.

Outside:

T: Ok, now it is time to get with our partners and do some investigating. Use the sheet provided to record your data for today, questions and connections.

The teacher will circulate with students to observe, conference and ask questions. Each set of partners should be charting data and making connections to the previous article in order to answer our focus question.

Concluding the lesson:

Figure 21. Lesson reflection led to the addition of the observation and inference review.

Current weather Temperature / humidity / wind / Sunshine	Current greenhouse conditions Temperature/ humidity/ wind / Sunshine	Observations

Figure 22. Data table edited by Samantha to reflect the addition of cloud cover or sunshine.

Initial thoughts from the Article	Article	Scientific Investigation

Figure 23. Connections chart edited by Samantha to provide clarity and lead to desired student outcomes.

Samantha began her lesson in her classroom instead of in the foyer, as Hannah had done previously. All of the students were seated at their desks, while Samantha stood at the board. She began the lesson by asking students what they had learned about the greenhouse effect from the article that they had read earlier in the day. The students responded at random. She then directed the students' attention to the learning target that was written on the board so that they could determine what the lesson was expected to teach them. She asked the students to identify the *What?* and *Why?* in the learning target in order to ground the students in what they would be working toward in the lesson.

From that point, Samantha activated students' prior knowledge in order to build a schema for students of what a greenhouse is and what it is used for. Samantha had drawn a greenhouse on the board and used this illustration to make a comparison of the structure of the greenhouse and the Earth's atmosphere. Samantha told students that when they went out to the greenhouse, they would use their observations to make inferences about the greenhouse and how it functions. She asked students to tell the difference between an observation and an inference. Once the students demonstrated an understanding of the difference between an observation and an inference, Samantha gave them instructions for what to bring to the greenhouse with them. The students took their science notebooks, the data sheet, and their article. Samantha had previously assigned the students to collaborative groups prior to beginning the lesson.

Once outside, the students stood on the sidewalk and recorded observations about the weather in their data tables (see Figure 13). They also talked about the connections to the functionality of the greenhouse and the connection to the function of the Earth's atmosphere. After the discussion, the students filed into the greenhouse, where they made and recorded more observations. Once the data collection was concluded, the students sat outside to analyze the data and record connections in the table provided on the student pages. Samantha led the students in a discussion to assess what connections they were making and then let them discuss in pairs as they recorded the connections on their student pages. The observing participants circulated as the students discussed. Samantha later debriefed the students and dismissed them back to her classroom.

Hannah and Christina had the responsibility of collecting data on both the students and teacher actions during the retaught lesson. Hannah sat and observed as the lesson progressed. The lesson began in the classroom, and Hannah sat next to Christina. They exchanged comments periodically throughout the introduction of the lesson. When the students left the classroom to go to the greenhouse, it was discovered that the greenhouse was in use by a different group of students. Hannah asked about the students using the greenhouse, and everyone waited until those students were done.

When Samantha's students entered the greenhouse to collect their data, Hannah sat on the sidewalk with Christina. Once the students exited the greenhouse to record their observations and discuss connections, Hannah sat under the overhang with Christina. They exchanged comments throughout the process. At one point after the students exited the greenhouse, Christina walked around to listen to the discussion and see what the students were writing. When the lesson concluded, the participants again elected to debrief immediately afterward in the conference room nearby.

Participant Data Collection

Christina noted in her data collection both commendations as well as criticisms of Samantha's teaching. She commented on the breakdown of the standard as a group at the beginning of the lesson, as well as how she called on multiple students. Christina noted how she loved the breakdown of the parts of the greenhouse, while also suggesting how to place more of the onus on students to come up with connections by letting them brainstorm before the teacher reveals her thoughts. Other commendations and recommendations can be found in the data collected on the lesson plan by Christina in Figure 24.

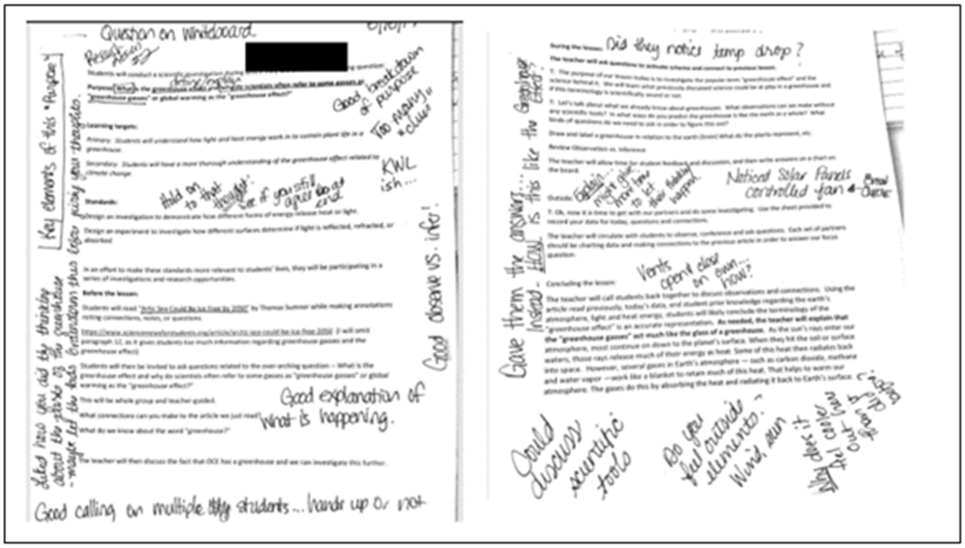
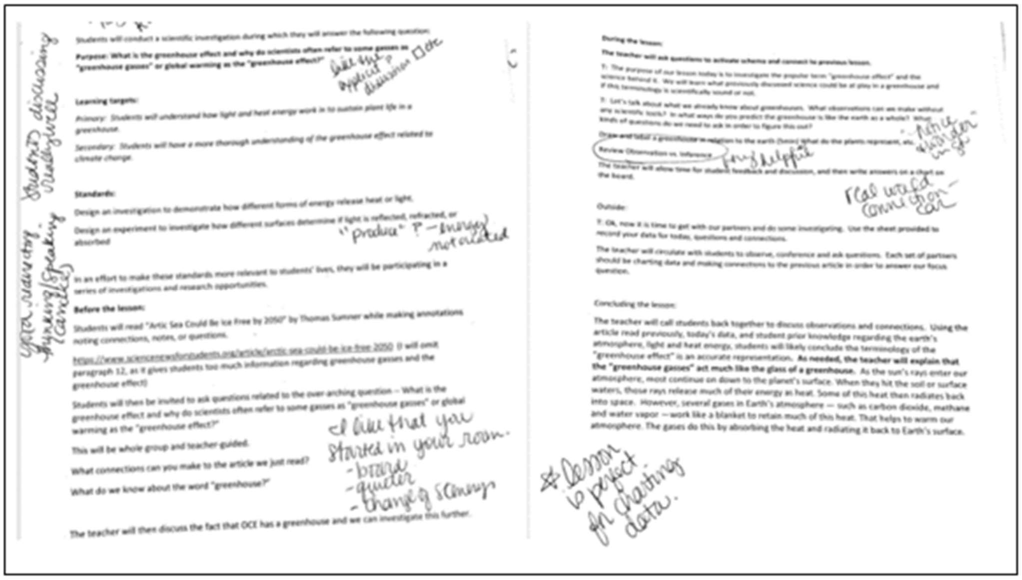


Figure 24. Data collected by Christina in the retaught lesson.

Hannah also collected data for the retaught lesson. Her data collection was not as detailed as the other participants. The comments that she made focused on what she had noticed in teacher practice. No data were collected by either participant on the student outcomes of the lesson. Hannah noted that she thought the explicit discussion of the standards at the beginning of the lesson was valuable and that the addition of the conversation around observation and inference with the students prior to data collection was a good addition to the lesson. An example of her data collection can be found in Figure 25.



Students will conduct a scientific investigation during which they will answer the following question:

Purpose: What is the greenhouse effect and why do scientists often refer to some gasses as "greenhouse gasses" or global warming as the "greenhouse effect?"

Learning targets:

Primary: Students will understand how light and heat energy work in to sustain plant life in a greenhouse.

Secondary: Students will have a more thorough understanding of the greenhouse effect related to climate change.

Standards:

Design an investigation to demonstrate how different forms of energy release heat or light.

Design an experiment to investigate how different surfaces determine if light is reflected, refracted, or absorbed

In an effort to make these standards more relevant to students' lives, they will be participating in a series of investigations and research opportunities.

Before the lesson:

Students will read "Artic Sea Could Be Ice Free by 2050" by Thomas Sumner while making annotations noting connections, notes, or questions.

https://www.sciencenewsforstudents.org/article/artic-sea-could-be-ice-free-2050 (I will omit paragraph 12, as it gives students too much information regarding greenhouse gasses and the greenhouse effect)

Students will then be invited to ask questions related to the over-arching question – What is the greenhouse effect and why do scientists often refer to some gasses as "greenhouse gasses" or global warming as the "greenhouse effect?"

This will be whole group and teacher guided.

What connections can you make to the article we just read?

What do we know about the word "greenhouse?"

The teacher will then discuss the fact that OCE has a greenhouse and we can investigate this further.

During the lesson:

The teacher will ask questions to activate schema and connect to previous lesson.

T: The purpose of our lesson today is to investigate the popular term "greenhouse effect" and the science behind it. We will learn what previously discussed science could be at play in a greenhouse and if this terminology is scientifically sound or not.

T: Let's talk about what we already know about greenhouses. What observations can we make without any scientific tools? In what ways do you predict the greenhouse is like the earth as a whole? What kinds of questions do we need to ask in order to figure this out?

Draw and label a greenhouse in relation to the earth (5min) What do the plants represent, etc.

Review Observation vs. Inference

The teacher will allow time for student feedback and discussion, and then write answers on a chart on the board.

Outside:

T: Ok, now it is time to get with our partners and do some investigating. Use the sheet provided to record your data for today, questions and connections.

The teacher will circulate with students to observe, conference and ask questions. Each set of partners should be charting data and making connections to the previous article in order to answer our focus question.

Concluding the lesson:

The teacher will call students back together to discuss observations and connections. Using the article read previously, today's data, and student prior knowledge regarding the earth's atmosphere, light and heat energy, students will likely conclude the terminology of the "greenhouse effect" is an accurate representation. **As needed, the teacher will explain that the "greenhouse gasses" act much like the glass of a greenhouse.** As the sun's rays enter our atmosphere, most continue on down to the planet's surface. When they hit the soil or surface waters, those rays release much of their energy as heat. Some of this heat then radiates back into space. However, several gases in Earth's atmosphere — such as carbon dioxide, methane and water vapor —work like a blanket to retain much of this heat. That helps to warm our atmosphere. The gases do this by absorbing the heat and radiating it back to Earth's surface.

Figure 25. Data collection by Hannah for the retaught lesson.

Research Lesson 2 Debriefing Session.

Rosy was unable to attend the debrief session due to a lack of prior notice, so the debriefing session was conducted without a facilitator. The researcher once again shared the norms of the meeting time, and the teaching participant reflected first. The first comment that Samantha made was an area of growth. She said that she noticed that she fed the students information as they were in the greenhouse. She wanted to work on her questioning skills, as doing so aligns with the state evaluation system.

An area that Samantha was proud of was how she began her lessons. She stated, "I guess a strength of the lesson might have been, I guess, towards the beginning something we've started more recently is breaking down the purpose of the lesson and the *what* and the *why*…that has helped them a lot and it's helped me a lot too, and it keeps me accountable, and so I guess that would have been a strength" (Retaught lesson debrief, 5/12/2017). Samantha was confident in her area of strength, grounding students in the purpose of the lesson, and she supported that with how students benefit from this practice.

Following Samantha’s reflection, the other participants shared their feedback. Christina was the first to offer feedback from the data that she had collected. She observed both the teacher and the students and offered reflections about both. Below is the feedback that Christina shared in the debrief session:

> That's impressive that you just said those things because those are the exact same things that I was going to say. That's like really cool. I actually wrote down that I thought it was awesome how you broke down the purpose. I wrote down that [you gave] too many clues, and that’s awesome that you already noticed that because that’s the hardest thing to figure out is how much [information] to feed and how much [information] to not feed, and I'm just noticing that’s really cool. I loved where you said, “Hold onto that thought to see if you still agree at the end.” That was awesome because you let that person hold that thought and decide for themselves whether they still agree. Now that's something that you can go back and check with him and see. I love that you called on multiple students and got some that were paying attention and had their hands raised and were wanting to pay attention and focus on what you knew. And I noticed like a KWL type thing. I liked how you did the thinking about the parts of the greenhouse inside the classroom and had a drawing on the board. I thought that was pretty neat. I did see a little bit of confusion, which was kind of interesting because it was where we were trying to have less confusion by adjusting the chart, and it just seemed to make more confusion than the initial [connections] chart. They didn't know what

the initial thoughts from the article and the article [columns] meant. It confused them, and I heard from their discussion that they didn't know why it was in [the data sheet] twice and we had tried. That's what we had said was an adjustment that we needed to make to make easier. So, it confused them more. (Transcript of retaught lesson debrief, 5/15/2017)

Christina’s feedback was both complimentary and affirming. In addition, she noticed some misconceptions that Samantha displayed, and she was able to point those out to Samantha. Following initial reflections, the participants discussed how the lesson could be changed to be better for the students, and what components of the lesson could be used in a science lesson for the school year to come. They said the following:

1-26 Christina: I think the most interesting part to me is the additional confusion based on something that we tried to do to alleviate confusion from.

1-27 Hannah: Yeah, I think maybe going back to the original format might be helpful or if they start the article part. . .

1-28 Christina: Or labeling differently.

1-29 Hannah: . . . Did they start the article part in the room? Like maybe if they had gone ahead and done the initial thoughts from the article.

1-30 Samantha: They did that in the morning. There were maybe a couple that didn’t.

1-31 Christina: And maybe that was one of the ones that we were talking about. So maybe relabeling these initial thoughts from the article, and then now thoughts from the article after seeing the greenhouse might have been. . .

1-32 Samantha: Yeah.

1-33 Christina: [It] might have been more accurate.

1-34 Hannah: Or maybe we just heard kids that weren't paying attention.

1-35 Christina: It easily could have been a kid that wasn't paying attention.

1-36 Hannah: Or a kid that didn't receive the initial instructions or did not compute them.

1-37 Christina: I'm thinking maybe we could do the scientific investigations, observations, initial thoughts from the article, and then combine the two integrated thoughts. That would be kind of neat. I love that you added the temperature, humidity, wind, sunshine thing to the weather.

1-38 Hannah: This was good.

1-39 Christina: I think this would be great at the beginning of the year. I agree, we really kind of need to just chart the data for all of this. And also, we can teach weather and climate with this too, because that would show that the time has to be there for the climate. Then you can predict the weather. That would be kind of neat actually. Then you could keep the data from year to year, and you could make an ongoing chart for this. That would be really cool. (Retaught lesson debriefing, May 2017)

Hannah was the second participant to offer feedback after Samantha had shared her evaluation of the lesson. She stated that she agreed with Christina's feedback, and she too liked how Samantha restated the question and the way she broke down the standard. Hannah mentioned that it was an element of Samantha's lesson that she wanted to implement in her classroom. She mentioned, "I like that you wrote down that question at the beginning, and I think I will try to do more with standards next year" (Retaught lesson transcript, 5/12/2017). Hannah was referring to how Samantha took the standard and let the students explain what was going to be learned in the lesson based on the *W* words (*what* and *why*) stated. Hannah pointed out that there was a statement made by a student that was a misconception about energy. “There were some misconceptions, like somebody mentioned like that the glass produced the energy” (Retaught lesson transcript, 5/12/2017). Hannah mentioned it to bring attention to the fact that it was noticed, and she followed the comment with a qualifier that this was a misconception across the grade level.

Hannah and Christina had given Samantha suggestions on how to amend the lesson for her group of students for the retaught lesson in the previous debrief. Hannah praised her implementation of the suggestions into the lesson. She said, “I do like that you decided to review the observation versus inference that was very helpful; we talked about that last week” (Retaught lesson transcript, 5/12/2017). Hannah liked the way that Samantha framed and reviewed this in class before going out to the greenhouse.

There was another suggestion made in the previous debrief concerning the data collection and reflection student pages. Hannah mentioned that the connections section of the chart still seemed to cause just as much (if not more) confusion for the students. She stated, “Yeah, I think maybe going back to the original format might be helpful or if they start the article part … maybe if they had gone ahead and done the initial thoughts from the article [before going to the greenhouse]” (Retaught lesson transcript, 5/12/2017). This statement showed a reflection on Hannah’s part because she had originally created the reflection chart. The initial revision was suggested because Hannah’s students did not understand the purpose of the chart. After everyone had shared their reflections, the debriefing session was concluded. This marked the end of the lesson study cycle.

Lesson Study Analysis

During the lesson study process, the participants collaboratively planned a science lesson to be taught by two teachers on two separate days, and subsequently debriefed following each teaching of the lesson. Throughout this process, similarities and differences were identified in the data that revealed the teaching practices observed. An exploration of the data collected during the lesson study process revealed a collective emphasis on charting data, investigations, discussion and discourse, observations and inferences, and student agency and responsibility. Each of these themes is discussed in this section.

Charting Data

The co-occurrence table in Table 9 for data collected during the lesson study process showed an emphasis on charting data as a means of supporting inquiry. Data collection or charting data was first mentioned in the collaborative planning session. Rosy led this session, and at the point where she was issuing a challenge to the group about student outcomes of this lesson, she asked, “What do you want students to do?” (Planning session, May 2017). The dialogue continued as follows:

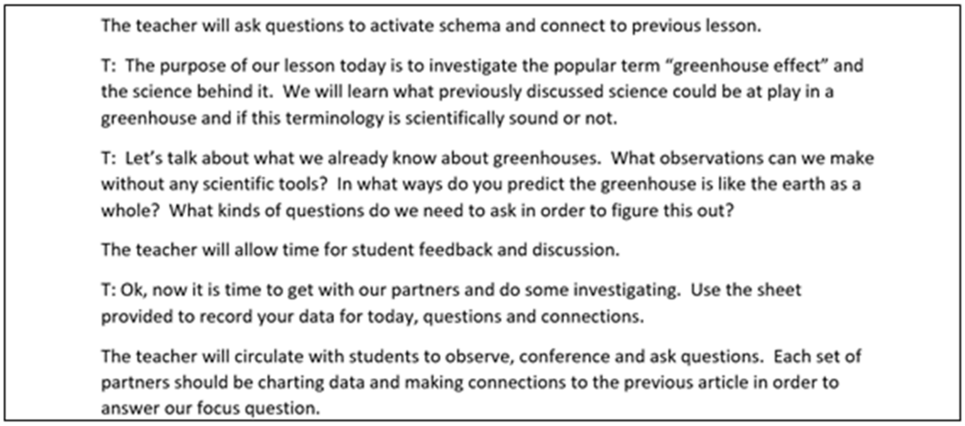
> 1- 75 Hannah: So, what investigations can we do at the greenhouse and then walk to the outdoors? So, like start at the outdoor classroom, walk to the greenhouse, close it back at the outdoor classroom. So, we can begin tracking on Thursday. We could track the data of the weather like how much sun, how clear is the day, how much light energy is getting to the roof.

1-76 Christina: I see what you're saying. In the morning versus the afternoon would be what?

1-77 Hannah: So, we can begin Wednesday morning tracking [these] data, and it would really be more of an introductory lesson. It becomes a jumping off point and then after seven days, I mean, but that is still conducting the investigation. They already know that these are producers, so they know that they are going to have light energy in order to make their own food. (CITATION?)

This dialogue was initiated by Rosy and continued between Hannah and Christina. Samantha did not contribute to this portion of the conversation in the planning. In the context of students engaging in investigations, charting data was important to the participants.

At the conclusion of the planning meeting, Hannah agreed to compile the thoughts shared in the meeting into a lesson plan that she would later execute for the first lesson in the lesson study cycle. She emailed this lesson plan (see Figure 26) to the rest of the group prior to teaching the lesson. In this lesson plan, Hannah noted specific instructions to use the sheets provided to record data from that day. Later in the lesson plan, she mentioned that the data collected would be used to make connections to the nonfiction text that the students would read prior to the lesson in order to answer the lesson's focus questions. For this lesson, it was apparent that charting data were a central connecting factor to the lesson.



The teacher will ask questions to activate schema and connect to previous lesson.

T: The purpose of our lesson today is to investigate the popular term "greenhouse effect" and the science behind it. We will learn what previously discussed science could be at play in a greenhouse and if this terminology is scientifically sound or not.

T: Let's talk about what we already know about greenhouses. What observations can we make without any scientific tools? In what ways do you predict the greenhouse is like the earth as a whole? What kinds of questions do we need to ask in order to figure this out?

The teacher will allow time for student feedback and discussion.

T: Ok, now it is time to get with our partners and do some investigating. Use the sheet provided to record your data for today, questions and connections.

The teacher will circulate with students to observe, conference and ask questions. Each set of partners should be charting data and making connections to the previous article in order to answer our focus question.

Figure 26. Section of Hannah's lesson plan for the first teaching of the research lesson.

In the debriefing session following the lesson enactment, the group had some discussion around data collection. Hannah and Christina gave suggestions to Samantha about how to improve the use of data collection for the lesson that she would be reteaching. It was noted by the participants that the students seemed to struggle in making connections (Research lesson debriefing, May 2017). In an attempt to clear up some student confusion, Christina suggested starting the data collection prior to starting the lesson. Hannah noted that because the data collection happened inside the greenhouse, it might have been challenging to complete this process prior to beginning the retaught lesson. The group conceded that the data collection process in this lesson could be a point at which to start a more regular routine of collecting data in the greenhouse and could be continued throughout the school year.

Following Samantha's reteaching of the research lesson when the group again met to discuss the lesson, data collection was again a valuable part of the discussion. Hannah and Christina praised Samantha for the additions that she had made to the original lesson plan for data collection, and they brainstormed ideas for future data collection in their classrooms. The dialogue proceeded as follows:

> 1-37 Christina: I'm thinking maybe we could do the scientific investigations, observations, initial thoughts from the article, and the combine the two integrated thoughts. That would be kind of neat. I love that you added temperature, humidity, wind, sunshine things to the weather.
>
> 1-38 Hannah: That was good.
>
> 1-39: Christina: I think that this would be great at the beginning of the year. I agree, we really kind of need to just chart the data for all of this. And also, we can teach weather and climate with this too because that would show that the time would have to be there for climate. Then you can predict the weather. That would be kind of neat actually. Then you could keep the data from year to year and you could totally make an ongoing chart from this.
>
> 1-40 Samantha: Yeah.
>
> 1-41 Christina: It can be a job. That could also teach. That goes into coding, writing and programming your Excel spreadsheets to do certain things.
>
> 1-42 Hannah: Somebody could easily have a job towards the end of the year making a spreadsheet to catalog the data from the average data that show that our climate is a very different climate. Some days it feels hot, and some days it feels very cold. (Retaught lesson debriefing, May 2017)

The inclusion of data collection was a consistent theme throughout the teaching planning and reteaching of the collaboratively planned research lesson. The data revealed that all participants agreed that charting data is a valuable practice in which students should engage.

Investigation

Throughout the lesson study process, the participants' discussion and practice emphasized investigations in science lessons. In the planning session, when discussing which topic to teach for the research lesson, the chosen standard included students engaging in designing an investigation. The group brainstormed around what lesson could actually be taught, which included the students engaging in investigating the chosen standard. When Rosy asked the group if they had truly taught their students how to do investigations, both Christina and Hannah answered that they do more inquiry than investigation in their classrooms. In spite of this fact, the group continued to plan a lesson to fit the chosen standard. The discussion proceeded as follows:

1-13 Hannah: An experiment, an investigation could be cooking with aluminum foil boxes…

1-14 Christina: (Interrupts) The solar panel.

1-15 Hannah: We talked about doing that. That would be, that would be so fun because that transfers the sun's energy into heat energy to cook your s'mores or whatever little thing you are cooking.

1-16 Samantha: (Affirmative response).

1-17 Rosy: So, is that what you are thinking that you will do for this investigation?

1-18 Christina: Well, we had planned on doing that at the end of the year, so if we want to do this on Friday, I think that we might need to do something to build up to that, so, and still do that. As far as the end-of-the-year project, we can use some of this stuff to do. They can investigate refraction and reflection.

1-19 Rosy: What do we have outside?

1-20 Hannah: The greenhouse.

1-21 Christina: Greenhouse. The greenhouse absolutely.

1-22 Hannah: (Interrupts) The light energy is transferred to…

1-23 Christina: And the heat energy.

1-24 Rosy: So, what can we do for a lesson? You are trying to get them to investigate? And let's back up. Have you all taught them to truly investigate?

1-25 Christina: We've done more inquiry than like investigations.

1-26 Hannah: That's on my list for the beginning of the year, just to unroll that just right off so that we do more investigating so instead of teaching that in with every standard, I want to teach that upfront.

1-27 Samantha: (Affirmative response)

1-28 Hannah: What investigations would be appropriate for what, and so that we can have that conversation all year? I don't think I did a very good job with that all this year.

1-29 Christina: No, mine has been more inquiry.

1-30 Rosy: So, for this lesson, what do you think you can do? How can you use what you have? You are leading up to the solar power you said, and what do you want them to get out of it? You want them to know what?

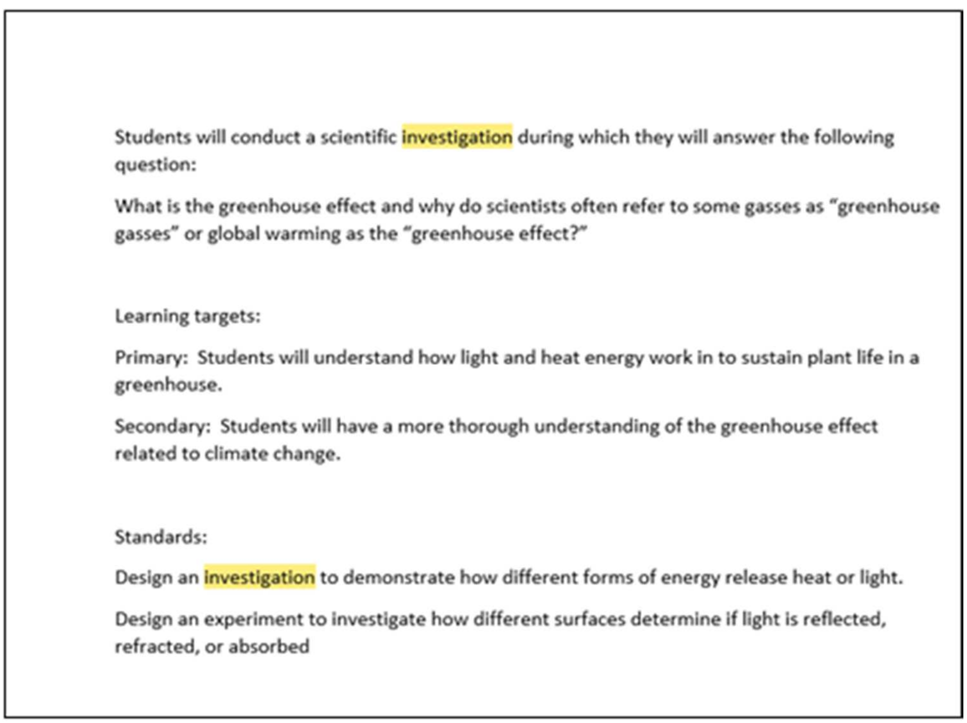
1-31 Hannah: I want them to know that heat energy, OK, I want them to know that different forms of energy release heat or light.

1-32 Hannah: So what investigations can we do at the greenhouse and then walk to the outdoor classroom? So, like start at the outdoor classroom, walk to the greenhouse, close it back at the outdoor classroom.

(Lesson planning transcript, 5/2/2017)

The majority of the planning session centered on how to plan a lesson in which the students completed an investigation to execute the agreed-upon standard. Some teachers noted more inquiry or discovery learning in science than engaging in investigations in which the students experimented to find the answer to a scientifically oriented question.

In the lesson plan, the lesson aim (the recorded state science standard) and the purpose of the lesson included an emphasis on students engaging in an investigation (see Figure 27).



Students will conduct a scientific investigation during which they will answer the following question:

What is the greenhouse effect and why do scientists often refer to some gasses as "greenhouse gasses" or global warming as the "greenhouse effect?"

Learning targets:

Primary: Students will understand how light and heat energy work in to sustain plant life in a greenhouse.

Secondary: Students will have a more thorough understanding of the greenhouse effect related to climate change.

Standards:

Design an investigation to demonstrate how different forms of energy release heat or light.

Design an experiment to investigate how different surfaces determine if light is reflected, refracted, or absorbed

Figure 27. Lesson aim and standards for the research lesson.

Although the group seemed to prioritize planning for students to engage in investigation in the greenhouse, the enacted lesson did not include students designing an investigation. Students collected and recorded data and discussed connections, but no experimental design was observed. In the debriefing session for the research lesson taught by Hannah, there was only one mention of an investigation, and it was in the context of doing future work (Research lesson debriefing, May 2017. The same was true of the lesson retaught. The students did not engage in designing an investigation, and again, there was no mention of investigations in the debriefing session.

Observation and Inference

During the research lesson enactment, the participants wanted to ensure that the students were making observations. The theme was included because there was no mention of students making observations or the necessity of that skill being included prior to the lesson study; this choice was made independent of the co-occurrence table. However, there was a consistent emphasis on it during the lesson study process. Although there was no mention of including the skill mentioned in the planning meeting, when Hannah sent the lesson plan to the group, making observations was included. The lesson plan included a few instances in which Hannah felt it necessary to center students on the use of observation skills in completing the learning target for that lesson. She chose to introduce the lesson by asking students what observations could they make without using scientific tools (Lesson plan for research lesson, May 2017).

During the lesson, the students made specific observations related to the greenhouse, and to conclude the lesson, Hannah asked students to make connections to the observations they had made to the nonfiction text that was read prior to the start of the lesson. The use of observational skills was critical to this lesson.

During the debriefing session following Hannah and Christina’s feedback, both felt that the observation portion of the lesson needed to be revised on the student-facing material in order to provide clarity. They expressed the following concerns:

> 1-3 Christina: I was noticing that they don’t necessarily know the difference between an observation and an inference. It is one of those things that needs to be clarified with kids that an observation is one of those things that you can see, feel, touch, and taste.
>
> 1-66 Hannah (talking to Samantha): I would have them go ahead and make connections between the article and the greenhouse. I didn't really want them to do this part ahead of time; however, you could change this to a three-column table and have them go ahead and write down some of their observations or inferences from the article, and then connections between the article and their scientific standards. (Research lesson debriefing session, May 2017)

In this instance, they agreed upon the idea of adding explicit instructions for observation and inference to the retaught lesson.

During the retaught lesson, Samantha included a specific portion of the lesson in which she explicitly led the students in a discussion of the difference between an observation and an inference prior to going outside to the greenhouse. The other participants spoke favorably of the enactment of the changes to the lesson plan. Hannah spoke specifically about it, to which the other participants agreed.

> 1-8 Hannah: I like that you stated it in your room. I think that worked out well having the board; it was a little bit quieter. And just having that change of scenery. I do like that you decided to review the observation vs. inference; that was very helpful. We talked about that last week. I liked that you praised their observations inside the greenhouse as notice and wonder. (Retaught lesson debriefing session transcript, May 2017)

Participant emphasis on the students' understanding and implementation of observations and inferences in the research lesson, and additionally in the retaught lesson, resulted from observations that the students were experiencing confusion when trying to complete the student pages following the data collection in the greenhouse. This was a responsive adjustment to a lack of student understanding and a positive step to improve student outcomes.

Discussion and Discourse

The orchestration of student discourse was one of the initial *a priori* codes that was chosen because of its significance in supporting inquiry in the science classroom. There was a marked difference in the emphasis on discussion and discourse, as the participants observed each other's teaching during the lesson study, compared to participant emphasis on discourse prior to engaging in lesson study. The first indication of planning for student discourse appeared in the lesson plan for the research lesson created by Hannah. The lesson plan revealed a need to provide opportunities for students to engage with the content through discussion. An excerpt from the lesson plan includes questions that would be posed to the students in an attempt to promote discourse in Figure 28.

During the lesson:

The teacher will ask questions to activate schema and connect to previous lesson.

T: The purpose of our lesson today is to investigate the popular term "greenhouse effect" and the science behind it. We will learn what previously discussed science could be at play in a greenhouse and if this terminology is scientifically sound or not.

T: Let's talk about what we already know about greenhouses. What observations can we make without any scientific tools? In what ways do you predict the greenhouse is like the earth as a whole? What kinds of questions do we need to ask in order to figure this out?

The teacher will allow time for student feedback and discussion.

T: Ok, now it is time to get with our partners and do some investigating. Use the sheet provided to record your data for today, questions and connections.

The teacher will circulate with students to observe, conference and ask questions. Each set of partners should be charting data and making connections to the previous article in order to answer our focus question.

Concluding the lesson:

The teacher will call students back together to discuss observations and connections. Using the article read previously, today's data, and student prior knowledge regarding the earth's atmosphere, light and heat energy, students will likely conclude the terminology of the "greenhouse effect" is an accurate representation. As needed, the teacher will explain that the "greenhouse gasses" act much like the glass of a greenhouse. As the sun's rays enter our atmosphere, most continue on down to the planet's surface. When they hit the soil or surface waters, those rays release much of their energy as heat. Some of this heat then radiates back into space. However, several gases in Earth's atmosphere — such as carbon dioxide, methane and water vapor —work like a blanket to retain much of this heat. That helps to warm our atmosphere. The gases do this by absorbing the heat and radiating it back to Earth's surface.

Figure 28: Excerpt from the first research lesson plan for discourse.

Hannah included question prompts to promote discussion, and at the onset of the lesson, she led students in a whole group discussion to make connections to what was read in the nonfiction text prior to engaging in the greenhouse lesson, and the observations and data collected while in the greenhouse.

Data collected by the non-teaching observers of the research lesson revealed how each one elevated the importance of student discourse or discussion in the lesson. Samantha, while observing Hannah's teaching, often recorded the questions that were being asked of students about the content (see Figure 29) and also recorded some of the students' responses.

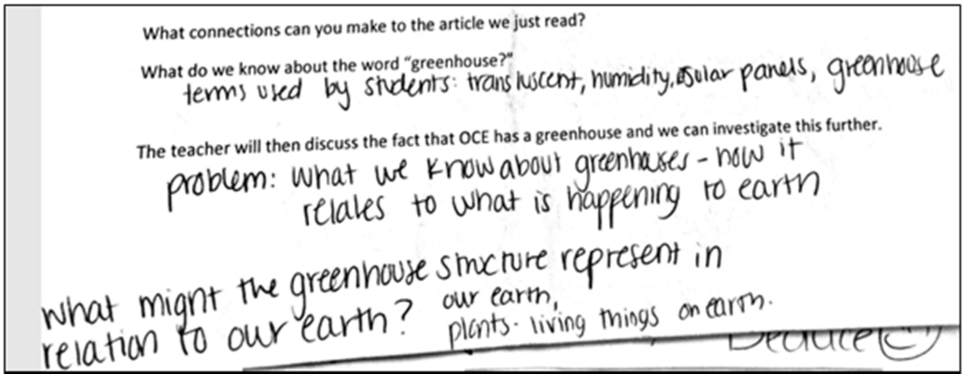


Figure 29. Samantha's data collection for Hannah's research lesson emphasizing teacher questions.

Christina's data collection during Hannah's lesson also noted questions that were asked of the students, as well as the responses those questions elicited, with special notes of the vocabulary used when the students answered the questions (see Figure 30).

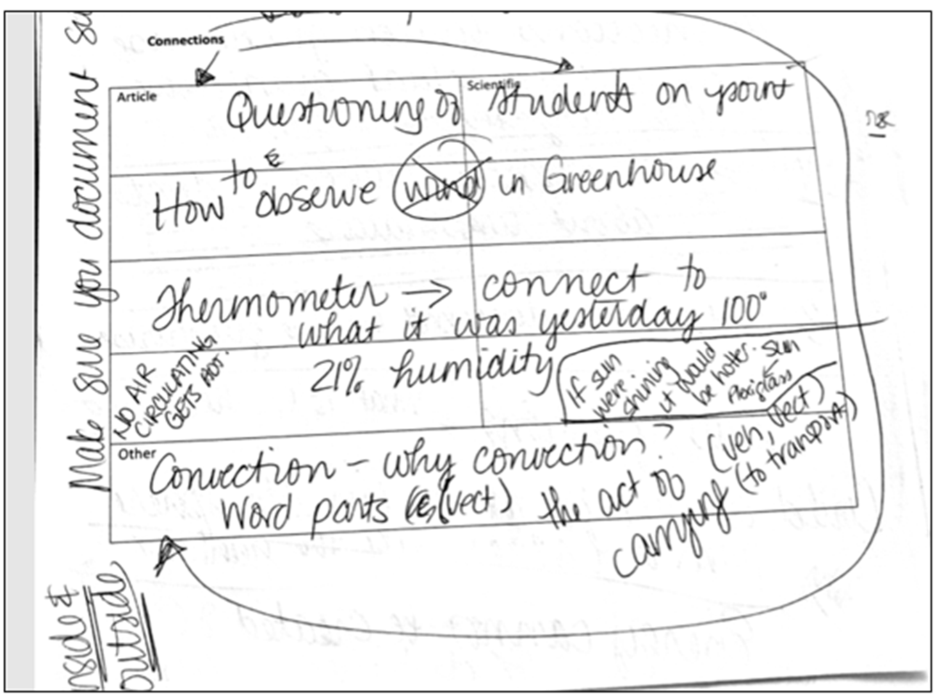


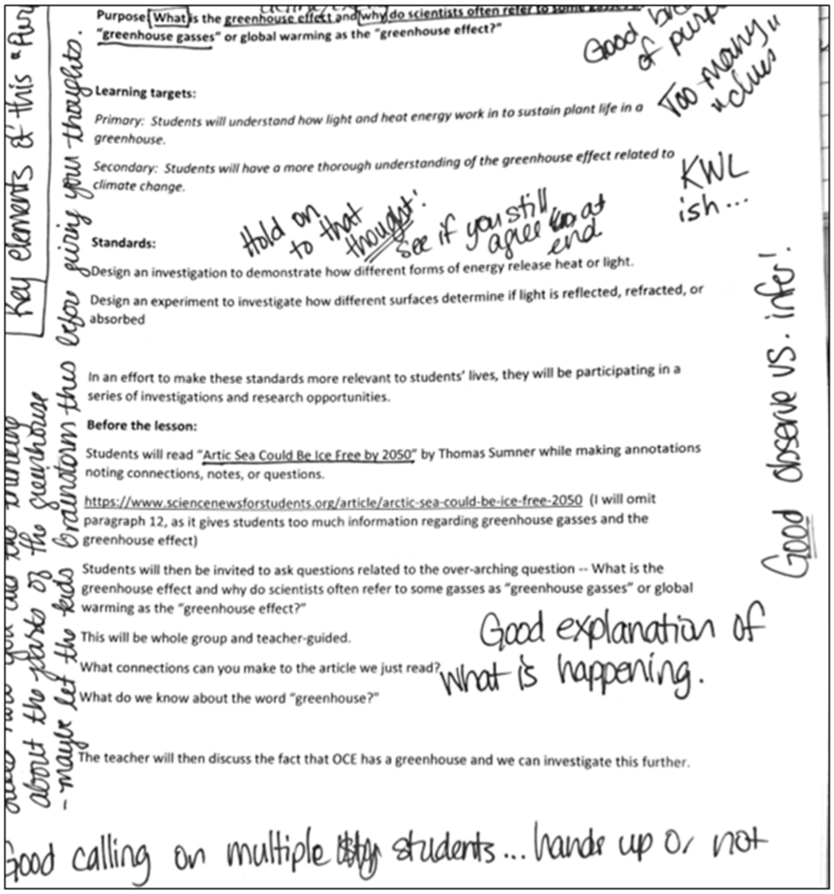
Figure 30. Example of Christina's data collection during the research lesson.

During the debriefing session following the research lesson, Christina shared feedback on the data that she had collected by expressing the following:

> 1-14 Christina: I love, your verbiage was great. I loved that you use big words where sometimes they would know them and sometimes, they had to ask.
>
> I wrote...I liked the discussion between the students about the temperature. I was writing down some of their questions: "Could the amount of gasses in our atmosphere form a barrier like the greenhouse?" That was a cool question. That was pretty neat. (Transcript of research lesson debriefing session, May 2017)

She was complimentary of the discussion led by Hannah in which the students engaged. Hannah mentioned that she wanted to be more engaging in how she orchestrated the discourse in her classroom, particularly for her higher-level students (Transcript of research lesson debriefing session, May 2017).

Christina's observations around discourse for Samantha's retaught lesson were similar to that of Hannah's, with the inclusion of suggestions for increased student responsibility and the mention of a potential misconception (see Figure 31). Christina commented on how Samantha called on multiple students to engage in the lesson and how she responded to those students. In addition, she made comments to suggest a need to make an adjustment in future lessons.



Purpose: What is the greenhouse effect and why do scientists often refer to some gasses as "greenhouse gasses" or global warming as the "greenhouse effect?"

Learning targets:

Primary: Students will understand how light and heat energy work in to sustain plant life in a greenhouse.

Secondary: Students will have a more thorough understanding of the greenhouse effect related to climate change.

Standards:

Design an investigation to demonstrate how different forms of energy release heat or light.

Design an experiment to investigate how different surfaces determine if light is reflected, refracted, or absorbed

In an effort to make these standards more relevant to students' lives, they will be participating in a series of investigations and research opportunities.

Before the lesson:

Students will read "Artic Sea Could Be Ice Free by 2050" by Thomas Sumner while making annotations noting connections, notes, or questions.

https://www.sciencenewsforstudents.org/article/arctic-sea-could-be-ice-free-2050 (I will omit paragraph 12, as it gives students too much information regarding greenhouse gasses and the greenhouse effect)

Students will then be invited to ask questions related to the over-arching question -- What is the greenhouse effect and why do scientists often refer to some gasses as "greenhouse gasses" or global warming as the "greenhouse effect?"

This will be whole group and teacher-guided.

What connections can you make to the article we just read?

What do we know about the word "greenhouse?"

The teacher will then discuss the fact that OCE has a greenhouse and we can investigate this further.

Figure 31. Example of Christina's data collection in the retaught lesson during Samantha's teaching.

During the debriefing session, Christiana shared with Samantha the following around the facilitation of the student discussion:

> Christina: I wrote down that [you gave] too many clues, and that's awesome that you already noticed that because the hardest thing to figure out is how much [information] to feed and how much [information] to not feed, and I'm just noticing that's really cool. I loved where you said, "Hold on to that thought to see if you still agree at the end." That was awesome because you let that person hold that thought and decide for themselves whether they still agree. Now that's

> something that you can go back and check with him and see. I love that you called on multiple students and got some that were paying attention and had their hands raised and were wanting to pay attention and focus on what you knew. (Transcript of retaught lesson debriefing session, May 2017)

This difference in the type of feedback might be a function of Christina's desire to provide constructive feedback to the less experienced teacher.

Connections to Individual Teacher Practices

The research lessons reflected some connections to individual teaching practices of the participants. The research lesson centered around connections made to a nonfiction text, which introduced students to the idea of the greenhouse effect. Both Hannah and Christina mentioned in their writing prompts that they like to choose a text for students to engage with for science instruction. During the planning phase of the research lesson, there was no mention regarding the use of a nonfiction text. However, when Hannah submitted the completed lesson plan, she included an article for students to reference and to use to make connections. When the team debriefed about the lesson, they did not elect to remove the text, but rather to amend the connections chart. All participants utilized some form of lecture at some or most of the lessons that were submitted via video. During the research lesson, both teachers began the lessons with a mini-lecture.

Inquiry Continuum

As a group collaboratively planning a research lesson through lesson study, the Inquiry Continuum can be used to characterize their teaching, as outlined in Figure 32. The research lesson was aligned to all features characterized in the continuum. For the first feature, learners engaged in scientifically relevant questioning in the research. When discussing the greenhouse and how it works, the learners posed questions rather than simply responding to them. During the research lesson, the learners were directed to collect data to provide evidence for any claims that they made. This activity aligned with the second essential feature on the continuum. The research lesson asked students to record their thoughts about the investigation using sentence stems provided by the teacher. Essential features three and five assess how students formulate and communicate explanations from evidence. In this lesson, the learner was given ways to use the evidence to make explanations. The nonfiction text provided to students was intended to be used to make connections to the investigation of how greenhouses work. This portion of the lesson aligned with essential feature four, which describes the ability of the learner to connect evidence to scientific knowledge.

Essential Feature	Variations			
1. The learner is engaged in scientifically oriented questions.	The learner poses a question.	The learner selects among questions; poses a new question.	The learner sharpens or clarifies a question posed by teacher, materials, or other sources.	The learner engages in questions provided by teacher, materials, or other sources.
Group		x		
2. The learner gives priority to evidence in responding to questions.	The learner determines what constitutes evidence and collects it.	The learner is directed to collect certain data.	The learner is given data and asked to analyze them.	The learner is given data and told how to analyze them.
Group		x		
3. The learner formulates explanations from the evidence.	The learner formulates an explanation after summarizing the evidence.	The learner is guided in the process of formulating explanations from the evidence.	The learner is given possible ways to use evidence to formulate an explanation.	The learner provided with evidence.
Group			x	
4. The learner connects evidence to scientific knowledge.	The learner independently examines other resources and forms the links to explanations.	The learner is directed toward areas and sources of scientific knowledge.	The learner is given possible connections.	
Group		x		
5. The learner communicates and justifies explanations.	The learner forms a reasonable and logical argument to communicate explanations.	The learner is coached in the development of communication.	The learner is provided with broad guidelines to sharpen communication.	The learner is given steps and procedures for communication.
Group			x	
	More-----------Amount of Learner Self Direction-----------Less Less--- Amount of Direction from Teacher or Material --- More			

Figure 32. Whole case teaching practice on the Inquiry Continuum.

Prior to lesson study, the instructional practices of the group of participants included only one of the essential features, essential feature one. The common thread was an opportunity for learners to engage in scientifically oriented questions, although none of the questions were generated by students. This was at the farthest end of the continuum, which exhibited a teacher-centered focus of those portions of the teacher lessons. As a group, when engaging with the research lesson, instructional practices were chosen that were categorized on the more student-centered end of the spectrum, as students were given the opportunity not only to engage in the questions posed by teachers but also to pose questions. Additionally, whereas only one to three essential features were observed in the submitted lessons by the individual participants, in the research lesson, all of the essential features were present and exhibited in varying degrees.

Two of the remaining essential features were closer to the student-directed end of the continuum, features two and four. Essential feature two focused on how the learner answered questions by using supporting evidence. This feature was not at the farthest end of the spectrum for teacher-directed teaching: the students were directed in terms of what data to collect by the teacher in the charts (which were found in the student packet) rather than the teacher giving the data to the students. Participants were placed in the center of the continuum for essential feature four because learners were able to connect evidence to scientific knowledge, given that the teacher provided a nonfiction text for students to make connections. The students were not given connections, but rather were guided in the research lesson to make connections using the connections chart provided.

The final two essential features, three and five, were more teacher-directed, but were not at the farthest end of the continuum. For the third essential feature, the groups' instructional practices were closer to the teacher-directed end of the spectrum, as there was no independence on the part of the student to formulate explanations from evidence. The sentence stems, as well as the connections charts provided by the teacher, guided students in how to use data evidence. During the research lesson, essential feature five was placed closer to the teacher-directed end of the continuum because the students were provided with guidelines through their student pages in terms of how to make connections to sharpen communication in their discussions with their partners.

Chapter Summary

Each participant came to the lesson study process with her own individual teaching practices. The Inquiry Continuum (NRC, 2000) was used to characterize each participant's practice prior to engaging in the lesson study process. Within the lesson study process, the teachers worked collaboratively to create a lesson in order to remediate a standard that was previously covered. They chose to use the greenhouse on campus to promote scientific investigations in the research lesson. During the lesson study process, it was revealed that the group emphasized the practices of collecting and charting data, along with students engaging in scientific investigation. In addition, there was a marked difference in emphasis within the lesson study context as opposed to individual emphases. The group emphasized the importance of discussion, which was not mentioned prior to the lesson study process. Data collected by the participants and debriefing sessions provided an opportunity to give and receive direct feedback regarding teaching practices. At the conclusion of the process, the whole group's lessons were again characterized using the Inquiry Continuum for scientific inquiry. There was a difference in lesson placement along the Inquiry Continuum from a solely teacher-centered method of instruction as individuals, to a more student-centered approach in the research lesson, with evidence of all essential features present to varying degrees. A discussion of the results, including implications and suggestions for future research, will follow in the next section.

CHAPTER FIVE: DISCUSSION

Introduction

In the U.S., typical elementary science instruction has not supported young children engaging in sophisticated scientific practice or developing deep understandings of appropriate science concepts (Banilower et al., 2013; Trygstad et al., 2013; Weiss et al., 2003). This is inconsistent with the current reform efforts set forth in *A Framework for K-12 Science Education* (NRC, 2011) and the original mandates of the National Science Education Standards (NRC, 1996) that encouraged a reformed method of teaching. Effective professional development can support teachers as they endeavor to be adequately prepared to meet the demands of the reform efforts (Desimone et al., 2002). Therefore, as previously stated, this study sought to examine the potential that engagement in the lesson study process might foster in supporting the professional development of elementary science teachers.

In this section, the purpose and significance of the study will be restated followed by a review of the methodology that was utilized by the researcher. Next, a review of the results of the study will follow. Finally, the results will be discussed, and this will include implications of the study and recommendations for future research.

Purpose of the Study

The purpose of this study was to examine the potential of the lesson study process in supporting elementary science teachers' PD. Specifically, by exploring teaching practices as the participants collaboratively planned and taught science lessons, this study sought to address the following question: How does instructional practice enacted within a science research lesson of a lesson study cycle compare to the typical instructional practices of fourth-grade teachers in science?

This study intended to add to the body of research in science education in two primary ways. First, this study contributed to the existing body of research that focuses on instructional practices for teaching science at the elementary level with a focus on in-service teachers as opposed to preservice teachers. Next, this study added to the body of research that focuses on the use of lesson study in U.S. classrooms as a means for improving teacher instructional practice and, in turn, student achievement, particularly in science.

Review of the Methodology

The researcher employed an embedded case study design (Yin, 2013) in an attempt to examine the potential of engagement in lesson study for supporting professional development in elementary science teachers. The study specifically sought to explore typical science teaching practice of a group of fourth-grade teachers compared to their teaching practices in a research lesson of a lesson study cycle. Analysis of each embedded case allowed the researcher to notice similarities and differences in the instructional practice of each participant. A cross-case analysis was also conducted which allowed the researcher to recognize patterns that arose during the planning and implementation of the research lessons in the lesson study cycle.

The study began with a planning meeting with the teachers and the knowledgeable other to set dates for all portions of the lesson study. Also, during that meeting the researcher collected writing prompts and requested video lessons of each teacher's typical science teaching in their classroom. The researcher was able to collect and retain two videos out of the three requested. These videos were analyzed using the Teaching Dimensions Observation Protocol (TDOP) (see Appendix C). The lesson study proceeded with the initial planning meeting in which the participants, with the aid of the knowledgeable other, planned the first research lesson and decided which teachers would teach. This meeting was audio recorded and subsequently transcribed. The next phase of the lesson study consisted of the first teaching of the research lesson. During the lesson, non-teaching participants collected data by observing both the teacher and the students as the research lesson progressed. The lesson was video recorded, transcribed, and also analyzed using the TDOP. The research lesson was followed by a debriefing session in which the participants shared the data that was collected and amended the lesson for the second teaching of the research lesson. Soon thereafter, the second research lesson was taught by Samantha in her classroom. Once again, the non-teaching participants collected data to be shared in the proceeding debriefing session. Immediately following the research lesson, the debriefing session convened where data collected by the non-teaching participants were shared and recommendations for the following year were discussed. Again, this debriefing session was audio recorded and subsequently transcribed.

The researcher utilized Atlas.ti software to analyze the data from the study. All data sources were uploaded into the software and coded using a priori codes that were established by the researcher based on literature on reform-oriented science teaching. Using these codes, networks were created and subsequently sorted for theme development.

Summary of the Results

The researcher sought to determine instructional practices of each teacher prior to engaging in lesson study. To this end, data representing the teachers' practice prior to the lesson study intervention (i.e., a writing prompt and teaching video) were used for this determination. Results of this initial analysis revealed teaching emphases for each participant.

Prior to Lesson Study

Based on her writing prompt submission, Hannah emphasized full integration of science content into other subjects in her lesson planning and implementation, including reading, mathematics, or social studies via current events. Hannah's video lesson submissions revealed a teacher-centered emphasis on engaging students in questioning around scientific content as stated by the first essential feature of the Inquiry Continuum. Similarly, an emphasis on content integration was shown in Samantha's writing prompt as well as beginning with a content standard as the foundation of lesson planning and implementation. Samantha's instructional practices, according to the Inquiry Continuum, also encompassed the first essential feature of engaging students in scientifically oriented questions but were more student-centered. Finally, Christina's writing prompt revealed an emphasis consistent with that of the other participants in that they all started with a standard and sought connections to other content areas for the purpose of integration. Christina's instructional practices also aligned with the first essential feature on the Inquiry Continuum of engaging students in scientifically relevant questions which also happened to be teacher-centered in nature. Collectively, the participants planning and implementation prior to the lesson study focused on content integration with little emphasis on student-centered scientific inquiry.

Through analysis of the case descriptions, commonalities in planning and implementation among the embedded cases were identified. These included beginning planning with a non-science state standard and planning that was collaborative in nature. Other commonalities included an emphasis on the use of non-fiction texts shared by Hannah and Samantha and an emphasis on the use of inquiry or discovery learning shared by Samantha and Christina. The group's teaching practices reflected the first essential feature (i.e., the learner engaged in scientifically oriented questions), but the instruction was largely teacher-focused.

There was a notable difference in instruction identified among the participants. Samantha mentioned a more varied approach to planning and implementing science lessons in her classroom. Her submitted lesson included hands-on student engagement that was different from the teacher-centered, discussion-driven lessons submitted by the other participants.

Whole Group Lesson Study Results

During the lesson study process, analysis focused on the practices in planning and implementation of the whole group or case. As a group, instructional practices were identified and subsequently compared to that of the embedded cases or individual participants. Data analysis following the lesson study revealed that the group emphasized the practices of collecting and charting data along with students engaging in scientific investigations. In addition, there was an emphasis on the importance of discussion which was not mentioned prior to the lesson study process. Data collected by the participants and debriefing sessions provided an opportunity to give and receive direct feedback about teaching practices. At the conclusion of the process, the whole group's lessons were again characterized using the Inquiry Continuum for scientific inquiry. This analysis revealed an addition of Essential Features present in the research lesson that were previously absent in individual lessons along the Inquiry Continuum. Individual lessons along the Inquiry Continuum were solely teacher-centered, and the research lesson was more student-centered with evidence of all essential features present in varying degrees. These results are summarized in Table 10.

Table 10

Summary of Results

Case	Instructional Emphasis	Essential Features
	Prior to Lesson Study	
Hannah	Collaborative planning Content integration Use of nonfiction text	Essential Feature One
Samantha	Collaborative planning Content integration Use of inquiry	Essential Feature One Essential Feature Three Essential Feature Four
Christina	Collaborative planning Content integration Use of inquiry	Essential Feature One
	During Lesson Study	
Whole group	Charting/collecting data Discussion Investigation Observation and Inferences	Essential Feature One Essential Feature Two Essential Feature Three Essential Feature Four Essential Feature Five

Discussion of the Results

As a result of participation in the lesson study process, participants were supported in planning and implementing an inquiry-focused science lesson as a group, which was in contrast to the teacher-centered lessons that were both observed and reported as typical of their individual practice prior to engaging in the lesson study. These results were comparable to results reported by Grove (2011). Similar to this study, Grove observed middle school teachers' science instruction both prior to and during a lesson study. In contrast, though, Grove also observed the participants' instruction following the lesson study process. The results of his study indicated that the participants implemented agreed-upon, inquiry-oriented teaching strategies more readily when planned as a group than were implemented in individual teaching practices observed prior to engaging in the lesson study. Other studies that utilized lesson study were conducted that yielded comparable results. Dotger and McQuitty (2014), in a study of elementary science teachers, noted a shift in instructional practice from before to during the lesson study process. Carrier (2011) conducted research on effective teaching strategies using lesson study that yielded similar results of shifts in teaching strategies implemented in science lessons as well. However, the study was conducted on a larger scale (57 participants) and with pre-service teachers. The similarities in instructional shifts noted in the aforementioned studies as a result of lesson study lend support to the results of this study.

In the current study, the motivation for the decision to plan and implement inquiry-focused instructional practices in the research lesson rather than the teacher-center practices indicative of individual science lessons was unclear. Other studies have reported varied findings with regard to the reasons for instructional shifts from teacher-centered versus inquiry-focused instruction. For example, in research by Dotger and McQuitty (2014) participants reported collaboration in the lesson study group positively influenced a desire to implement inquiry-oriented science lessons. In another study, Carrier (2011) stated that participants cited the benefit of the lesson study elements (collaboration, discussion, and reflection) to their change in practice. Guttierez (2016) conducted research with 30 in-service elementary science teachers and reported that teachers were developed professionally by lesson study especially in the areas of improving teaching strategies aligned to inquiry. In a study of mathematics high school educators, Prince (2016) found that group enhancements were made to the research lesson in several ways and as a result the lesson became more focused and created rich opportunities for students to learn through problem solving. This experience would be synonymous to inquiry-based science instruction. In each of these studies, the researchers were able to surmise similar reasons for changes in instruction by the teachers as a result of participation in lesson study. Although the data in the current study did not allow for such a definitive determination of cause for the participants' decisions to adjust the lesson to an inquiry-based lesson, these studies provide insights into possibilities that are worthy of future investigation.

Other research on lesson study points to the significance of including a knowledgeable other in the planning and implementation of the lesson study process (Huang & Han, 2015; Huang & Shimizu, 2016; Lewis, 2016; Prince, 2016). In Prince's (2016) study, it was noted that the knowledgeable other directly influenced the shift that occurred related to the research lesson. Thus, the results of his study suggested that the knowledgeable other played a vital role in the success of research lessons. Likewise, Lewis (2016) mentioned the vital role of an external facilitator in advising participants throughout the lesson study process. Huang and Han (2015) as well and Huang and Shimizu (2016) also mentioned the significance of the inclusion of the knowledgeable other in the lesson study process for teacher learning. In the current study, the participants planned and implemented a more inquiry-focused science lesson as a group. Although causation cannot be confirmed, this literature suggests that the presence of the knowledgeable other has a positive impact on the research lesson planning and implementation; thus, it is a vital component of lesson study.

Implications

The results of this study have both theoretical and practical implications for science teacher education. Theoretically, the study lends support to the claim that using lesson study can support elementary teachers who typically rely on teacher-centered instruction in implementing an inquiry science approach that aligns with inquiry-science pedagogy. Practically, the study suggests that using lesson study as a professional development model provided an environment where teachers collaborated for improved instructional practices, particularly by including a knowledgeable other, who may have been a key factor in the observed difference in instruction in the research lesson. A description of both the practical and theoretical implications follows.

Theoretical Implications

Theoretically, the results of this study add to the body of research based on the potential benefits of using lesson study to improve instruction in elementary science classrooms. Science instruction in the U.S. has been the focus of reform efforts for decades (cf. AAAS, 1990; NGSS Lead States, 2013; NRC, 1996, 2000; NSTA, 2018).

Such reform efforts have championed a shift to a more inquiry-focused, student-centered approach to science instructional practices (NRC, 2000). In elementary science education, typical instruction (non-inquiry and teacher-centered) does not support young children's development of deep understanding of scientific concepts (Trygstad et al., 2013; Weiss et al., 2003). For these reasons, the results of this study bear theoretical significance. In this study, the results of participants' instructional practices were consistent with research on typical elementary science education. Conversely, during the lesson study, the participants' teacher-centered approach to science instruction as individuals was replaced by a more inquiry-focused, student-centered approach being planned and implemented in the research lesson. These results affirm the potential for lesson study to support teachers in implementing more reform-oriented instructional practices in elementary science classrooms.

Practical Implications

The practical implications of this study included the use of lesson study as a means of professional development for participants and the impact of the collaborative nature of planning and implementation, which can foster risk-taking in instruction. During the lesson study the participants' decisions regarding lesson structure and implementation were vastly different from the lessons conducted prior to lesson study. The results of this study can inform any stakeholder who is responsible for teacher professional development, including state, district, and school-level administrators.

Additionally, participants worked at a school that carried a STEAM designation which greatly emphasized the integration of all content areas with science, technology, engineering, art, and mathematics. Participants' prioritization involving the content integration of standards might have been due to the overarching goal of integration as a school. Prior to the lesson study while planning and implementing science lessons, teachers were inclined to begin planning with a standard from other content areas, which diverted attention away from engaging students in deeper science learning and meaningful content. The lesson study process, though, supported the development of a more inquiry-focused lesson. Both administrators and teacher leaders in STEAM schools should consider these results and note the potential for lesson study to focus teachers' attention toward scientific inquiry.

Areas of Future Research

This study focused on the instructional practices of a small group of teachers before engaging in lesson study and the observed instructional practice during planning and implementation of a research lesson. Although the results obtained can add to the body of literature on elementary science education and lesson study, further research is necessary. Three key areas of research emerged from the results of this study. First, the study was conducted on a small sample size. It would be beneficial to replicate this study with a larger sample size to see whether similar results might be obtained on a larger scale. Second, the context of the study should be considered for future research. This research was conducted in a medium-sized school district in a suburb located in a southern state. Moreover, the school had relatively homogenous demographics with respect to both faculty and student body. The body of research would benefit from similar research in a more demographically diverse setting. Finally, during the lesson study process, the participants made instructional decisions as a group that were different from science instruction displayed in the data collected in their individual instructional practices. The cause of this decision to adjust was not identified. Consequently, future study should be replicated, but with an emphasis on the impact of the knowledgeable other.

Chapter Summary

U.S. students continue to underachieve in science and mathematics (Martin, Mullis, & Foy, 2008; Martin, Mullis, Foy, & Hooper, 2016; Organization for Economic Cooperation and Development [OECD], 2008, 2010; Provasnik, Malley, Stephens, Landeros, Perkins, & Tang, 2016). A key factor contributing to student achievement is the teacher (Committee on Science and Math Teacher Preparation, 2001). Research shows that authentic professional development opportunities improve teaching practice, and thus, improve student achievement (Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009). To this end, the current study aimed to describe the experiences of teachers engaged in an authentic professional development opportunity: lesson study. This study intended to capture any differences in instructional practices as the lesson study progressed.

The results of this study revealed the value of lesson study in terms of supporting teachers in sampling inquiry-based instructional practice as opposed to the teacher-centered approach to science instruction displayed in individual classrooms. Although the cause of the adjustment in planning and implementation of an inquiry-based lesson was uncertain, it may be attributed to the inclusion of a knowledgeable other in assisting with the planning and implementation of the research lesson. Moreover, this study revealed the potential for lesson study as a viable means of professional development to promote improved elementary science instruction. Finally, the results of the study can inform professional development stakeholders as science education reform for all children continues to progress.

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APPENDIX A: Writing Prompt

Directions

Please complete the following writing prompt by responding in written format in the space provided. You may write on the back of this paper. Be as detailed as possible.

Please describe below the planning, implementation, and assessment process of a typical science lesson in your classroom by addressing the following questions fully and completely. Please include the process of choosing a particular activity and the criterion and any factors that affect this choice.

- Please describe below the process of planning a typical science lesson in your class.
- Please describe below the process of implementation of a typical science lesson in your classroom. (Describe materials used, origin of lesson, types and lengths of activities, as well as students' participation.)
- Please describe below the assessment process that you use during and following a typical science lesson.

Each question is provided on separate sheets below.

Please describe below the process of planning a typical science lesson in your class.

____

____

____

____

Please describe below the process of implementation of a typical science lesson in your classroom. (Describe materials used, origin of lesson, types and lengths of activities, as well as students' participation.)

Please describe below the assessment process that you use during and following a typical science lesson.

Please provide any additional comments in the space below.

APPENDIX B: Demographic Information

Please complete the following information:

1. Grade level you are now teaching:

   3 ____

   4 ____

   5 ____

   Other ____

2. Gender:

   F ____

   M ____

3. Years teaching experience at elementary level: ______yrs

4. Years of teaching at current grade: _______ yrs

5. Highest degree earned:

   BA/BS ____

   MS/MA ____

   Specialist ____

   Doctorate ____

Please indicate your answer preference for the items below by circling the appropriate letters:

6. If you had your choice, would you choose to be the one to teach science to your students?

   1. Definitely no

2. Probably no
3. Not sure
4. Probably yes
5. Definitely yes

7. Compared to the minimum amount of time I <u>should</u> spend teaching science, I spend:
    1. A lot less
    2. A bit less
    3. That exact amount
    4. A bit more
    5. A lot more
8. The major portion of my time in science instruction is spent in:
    1. Textbook-based presentation only
    2. More textbook-based presentation than anything else
    3. An equal amount of textbook-based presentation and activity-based instruction
    4. More activity-based instruction than textbook-based presentation
    5. Activity based instruction only
9. Please rate how you view your own effectiveness as a teacher of elementary science:
    1. Superior - One of the most outstanding teachers of elementary science in the building; a master teacher of elementary science

2. Above average
3. Average - A typical teacher of elementary science
4. Below average
5. Low - One of the least effective teachers of elementary science, in need of professional improvement in this area

10. Number of College Science Courses (estimate the number of courses NOT credit hours): ____

11. Describe any science related professional development in which you have participated:

12. Describe all science specific professional development that you have received that in the past 10 years.

APPENDIX C: Teaching Dimensions Observation Protocol (TDOP)

Teaching Dimensions Observation Protocol

TDOP Cover Sheet

On this cover sheet please fill in information about the purpose of the observation, instructor characteristics, and course characteristics. Some of this information will require a meeting/interview with the observed instructor, which is optional but recommended.

I. Observer Information

1) Observer name: ______________________________

2) Date and time of observation: ______________________________

IIa. Instructor Characteristics

1) Instructor name: ______________________________

2) Appointment type: ______________________________

3) Years teaching this course: ______________________________

IIb. Instructor Characteristics – Goals and plans

1) Goals for the observed class: ______________________________

2) Planned activities for the observed class: ______________________________

3) How the class fits into the larger course (e.g., exams, special activities): ______________________________

4) How instructor uses data, if at all, to refine and/or inform teaching: ______________________________

III. Course Characteristics

1) Class name and level: ______________________________

2) Department: ______________________________

3) What is the total number of students in the class at the time of the observation?

O 25 or fewer	O 200-300
O 26–50	O 300-400
O 51–100	O 400 -500
O 100-200	O 500 +

4) Please describe the physical layout of the room (e.g., type of student seating, technology directly accessible by students, instructor on dias, number of projection screens and their positioning, etc.)

5) Please note if there is anything unusual about this particular class/lecture (e.g., quiz day, first day of semester, etc.)

TDOP Teaching Dimensions Observation Protocol

Code Definitions & Coding Rules

Teaching Methods

Teacher-focused instruction (teacher is the primary actor)

L — **Lecturing**: The instructor is talking to the students and not using visuals, demonstration equipment, actively writing, or asking more than 2 questions in a row in a Socratic manner.

LW — **Lecturing while writing**: The instructor is talking to the students while actively writing on a chalkboard, transparencies, digital tablet, or other material. The instructor must either be writing or referring to what they are writing (or have already written). This code also captures real-time drawing of graphics (e.g., molecular structure, physiological processes), and if the use of visual representations is of interest, this should be included in the notes section. (Note that this code also captures writing/drawing in front of students without speaking, as a separate code for silent writing was deemed superfluous).

LVIS — **Lecturing from pre-made visuals**: The instructor is talking to the students while referencing visual aides, such as slides, transparencies, posters, or models (e.g., plastic model of molecular structure, examples of sedimentary rocks, multi-media). The instructor must be referring to the topic contained in the visual, but the visual serves only as a reference point for the material and not as a live demonstration of phenomenon.

LDEM — **Lecturing with demonstration of phenomena**: The instructor actively uses equipment (e.g., lab equipment, computer simulation) to convey course content. The objects must be in active use in relation to the topic and must be used for more than a simple reference point (e.g., "here is an example of a sedimentary rock") to demonstrate a process or phenomenon in class (e.g., "here is how sedimentary rock erodes over time" while physically demonstrating this process).

SOC-L — **Socratic lecture:** The instructor is talking to the students while asking multiple, successive questions to which the students are responding. Student responses are either guiding or being integrated within the discussion. A minimum of 2 relevant student responses is required to use this code. (Note that SOC-L can be co-coded with other types of lecturing, such as LW, if the instructor is doing both writing AND interspersing his/her talk with questions).

WP — **Working out problems:** This code refers to the instructor working out computations or problems. These can include balancing a chemical equation, working out a mathematical proof, or designing equations or Punnett squares, etc. The intent of the code is to capture the working through of some sort of problems in front of students. (If the computations/problems are on a slide and the instructor is actively working through problems, then this will be co-coded with LVIS. If this process is being written out, then this code will be co-coded with LW, and if students are being asked to participate in the problem-solving process via questions, code SOC-L).

IND — **Individualized instruction:** The instructor provides instruction to individuals or groups and not the entire class. This often occurs while the instructor is roaming the classroom, but students or small groups may also approach the instructor. This code is usually co-coded with SGW or DW (see below). It is important to recognize that this code should not be used to classify the types of student-teacher interactions that are occurring in a large class setting – instead, use this code only when students are engaged in SGW or DW and the instructor is directly interacting with one or more students.

MM — **Multimedia**: The instructor plays a video or movie (e.g., Youtube or documentary) without speaking while the students watch. If the instructor is talking over a video, movie, or simulation, then co-code with LVIS.

A — **Assessment**: The instructor is explicitly gathering student learning data in class (e.g., tests, quizzes, or clickers).

AT — **Administrative task:** The instructor is discussing exams, homework, or other non-content related topics.

Student-focused instruction (students are the primary actor)

SGW — **Small group work/discussion**: Students form into groups of 2+ for the purposes of discussion and/or to complete a task.

DW — **Deskwork:** Students complete work alone at their desk/chair.

SP — **Student presentation**: Groups or individual students are giving to the class or are otherwise acting as the primary speaker or instructor in the classroom. In this instance, only select this code and none others as long as the primary instructor is not actively taking the lead in teaching the class.

Student-Teacher Dialogue

Teacher-led dialogue

IRQ — **Instructor rhetorical question**: The instructor asks a question without seeking an answer and without giving students an opportunity to answer the question.

IDQ — **Instructor display question:** The instructor poses a question seeking information. These questions can: seek a specific fact, a solution to a closed-ended problem, or involve students generating their own ideas rather than finding a specific solution.

ICQ — **Instructor comprehension question**: The instructor checks for understanding (e.g., "Does that make sense?") and pauses for at least five seconds, thereby indicating an opportunity for students to respond.

TDOP Teaching Dimensions Observation Protocol

Student-led dialogue

SQ **Student question**: A student poses a question to the instructor that seeks new information (i.e. not asking to clarify a concept that was previously being discussed) **and/or** clarification of a concept that is part of the current or past class period.

SR **Student response to teacher question**: A student responds to a question posed by the instructor, whether posed verbally by the instructor or through digital means (e.g., clicker, website).

PI **Peer interactions**: Students speaking to one another (often during SGW, WCD, or SP).

Instructional Technology

CB **Chalkboard/whiteboard/Smart Board**

OP **Overhead projector/transparencies**

PP **PowerPoint or other digital slides**

CL **Clicker response systems**

D **Demonstration equipment**: These could include chemistry demonstrations of reactions, physics demonstrations of motion, or any other material being used for the demonstration of a process or phenomenon. The objects must be in active use in relation to the topic. This can also include objects such as rocks being passed around a classroom.

DT **Digital tablet:** This refers to any technology where the instructor can actively write on a document or graphic that is being projected onto a screen. This includes document cameras as well as software on a laptop that allows for writing on PDF files.

M **Movie, documentary, video clips, or Youtube video**

SI **Simulation:** Simulations can be digital applets or web-based applications.

WEB **Website:** Includes instructor interaction with course website or other online resource (besides Youtube videos). This can include using a website for student responses to questions (in lieu of clickers).

Pedagogical Strategies

HUM **Humor**: The instructor tells jokes or humorous anecdotes; this code requires laughter from at least a couple of students.

ANEX **Anecdote/example:** The instructor gives examples (either verbally through illustrative stories or graphically through movies or pictures) that clearly and explicitly link course material to (a) popular culture, the news, and other common student experiences, or (b) widely recognized cases or incidents that illustrate the abstract (both types are co-coded with CNL).

ORG **Organization**: The instructor writes or posts an outline of class (i.e., advance organizer) or clearly indicates a transition from one topic to the next verbally or through transitional slides. This transition from one topic to another can indicate a change in topics within a single class or from a previous class to the present class. These transitions must be verbally explicit statements to the class (e.g., "Now we're moving from meiosis to mitosis") as opposed to ambiguous statements such as "Now we'll pick up where we left off on Monday." This may also include statements concerning how concepts covered in different portions of the class (e.g., lecture, homework and lab) may overlap.

EMP **Emphasis:** The instructor clearly states that something is important for students to learn or remember either for a test, for their future careers, or to just learn the material well

Optional Dimensions

Potential Student Cognitive Engagement

CNL **Making connections to own lives/specific cases**: Students are given examples (either verbally through illustrative stories or graphically through movies or pictures) that clearly and explicitly link course material to popular culture, the news, and other common student experiences. Students may also be given specific cases or incidents in order to link an abstract principle or topic (e.g., flooding) with a more readily identifiable instance (e.g., 2013 floods in Boulder, Colorado). For this code to be used, the observer will need to make a judgment that the specific case is something meaningful to students, such as a local historic item or location, or a widely recognized incident. In general, a high bar is required here that is based on specificity and salience to students, such that showing a picture of a sedimentary rock will not be sufficient for this code, but if the picture was of the Grant Canyon and named as such, it would be coded as CNL. This code will be particularly important in biology (e.g., Dolly the sheep) and geoscience courses.

PS **Problem solving:** Students are asked to actively solve a problem (e.g., balance a chemical equation, work out a mathematical equation/algorithm). This is evident through explicit verbal (e.g., "Please solve for X") or written requests (e.g., worksheets) to solve a problem. **This is coded in relation to closed-ended exercises or problems where the instructor has a specific solution or end-point clearly in mind.**

CR **Creating**: Students are provided with tasks or dilemmas where the outcome is open-ended rather than fixed (e.g., students are asked to generate their own ideas and/or products rather than finding a specific solution). The task can be delivered verbally or in written form. **This is coded in relation to open-ended exercises or problems where the instructor does not have a specific solution or end-point clearly in mind.**

TDOP Teaching Dimensions Observation Protocol

Pedagogical Strategies

HUM **Humor**: The instructor tells jokes or humorous anecdotes; this code requires laughter from at least a couple of students.

ANEX **Anecdote/example:** The instructor gives examples (either verbally through illustrative stories or graphically through movies or pictures) that clearly and explicitly link course material to (a) popular culture, the news, and other common student experiences, or (b) widely recognized cases or incidents that illustrate the abstract (both types are co-coded with CNL).

ORG **Organization**: The instructor writes or posts an outline of class (i.e., advance organizer) or clearly indicates a transition from one topic to the next verbally or through transitional slides. This transition from one topic to another can indicate a change in topics within a single class or from a previous class to the present class. These transitions must be verbally explicit statements to the class (e.g., "Now we're moving from meiosis to mitosis") as opposed to ambiguous statements such as "Now we'll pick up where we left off on Monday." This may also include statements concerning how concepts covered in different portions of the class (e.g., lecture, homework and lab) may overlap.

EMP **Emphasis:** The instructor clearly states that something is important for students to learn or remember either for a test, for their future careers, or to just learn the material well.

Student Engagement

VHI **Very High:** More than 75% of the students in the immediate area of the observer are either (a) actively taking notes, or (b) looking at the instructor/course materials

HI **High:** Between 50% and 75% of the students in the immediate area of the observer are either (a) actively taking notes, or (b) looking at the instructor

MED **Medium:** Between 25% and 50% of the students in the immediate area of the observer are either (a) actively taking notes, or (b) looking at the instructor

LO **Low:** Less than 25% of the students in the immediate area of the observer are either (a) actively taking notes, or (b) looking at the instructor

Teaching Dimensions Observation Protocol

Directions: **Circle codes for each behavior observed during every two-minute interval. Take detailed notes about aspects of the class that is of particular interest for your application (e.g., content discussed, nature of student dialogue). Note: this template is for illustrative purposes only and includes the 3 Basic Dimensions and 2 Optional Dimensions (i.e. student engagement is not shown).**

Interval #	**1**	**2**	**3**	**4**	**5**
Min	0-1:59	2:00-3:59	4:00-5:59	6:00-7:59	8:00-9:59
Instruct. Practices – Teacher-focused	L LW LVIS LDEM SOC-L WP IND MM A AT	L LW LVIS LDEM SOC-L WP IND MM A AT	L LW LVIS LDEM SOC-L WP IND MM A AT	L LW LVIS LDEM SOC-L WP IND MM A AT	L LW LVIS LDEM SOC-L WP IND MM A AT
Instruct. Practices – Student-focused	SGW DW SP	SGW DW SP	SGW DW SP	SGW DW SP	SGW DW SP
Notes :					
Student-Teacher Interactions Teacher-led	IDQ ICQ IRQ	IDQ ICQ IRQ	IDQ ICQ IRQ	IDQ ICQ IRQ	IDQ ICQ IRQ
Student-Teacher Interactions Student-led	SQ SR PI	SQ SR PI	SQ SR PI	SQ SR PI	SQ SR PI
Notes:					
Instructional Technology	CB OP PP CL D DT M SI WEB	CB OP PP CL D DT M SI WEB	CB OP PP CL D DT M SI WEB	CB OP PP CL D DT M SI WEB	CB OP PP CL D DT M SI WEB
Notes:					
Potential Cognitive Demand	CNL PS CR	CNL PS CR	CNL PS CR	CNL PS CR	CNL PS CR
Notes:					

TDOP Teaching Dimensions Observation Protocol

Interval #	6	7	8	9	10
Min	10:00-11:59	12:00-13:59	14:00-15:59	16:00-17:59	18:00-19:59
Instruct. Practices – Teacher-focused	L LW LVIS LDEM SOC-L WP IND MM A AT	L LW LVIS LDEM SOC-L WP IND MM A AT	L LW LVIS LDEM SOC-L WP IND MM A AT	L LW LVIS LDEM SOC-L WP IND MM A AT	L LW LVIS LDEM SOC-L WP IND MM A AT
Instruct. Practices – Student-focused	SGW DW SP	SGW DW SP	SGW DW SP	SGW DW SP	SGW DW SP
Notes					
Student-Teacher Interactions Teacher-led	IDQ ICQ IRQ	IDQ ICQ IRQ	IDQ ICQ IRQ	IDQ ICQ IRQ	IDQ ICQ IRQ
Student-Teacher Interactions Student-led	SQ SR PI	SQ SR PI	SQ SR PI	SQ SR PI	SQ SR PI
Notes:					
Instructional Technology	CB OP PP CL D DT M SI WEB	CB OP PP CL D DT M SI WEB	CB OP PP CL D DT M SI WEB	CB OP PP CL D DT M SI WEB	CB OP PP CL D DT M SI WEB
Notes:					
Potential Cognitive Demand	CNL PS CR	CNL PS CR	CNL PS CR	CNL PS CR	CNL PS CR
Notes:					

TDOP Teaching Dimensions Observation Protocol

Interval #	11	12	13	14	15
Min	20:00-21:59	22:00-23:59	24:00-25:59	26:00-27:59	28:00-29:59
Instruct. Practices – Teacher-focused	L LW LVIS LDEM SOC-L WP IND MM A AT	L LW LVIS LDEM SOC-L WP IND MM A AT	L LW LVIS LDEM SOC-L WP IND MM A AT	L LW LVIS LDEM SOC-L WP IND MM A AT	L LW LVIS LDEM SOC-L WP IND MM A AT
Instruct. Practices – Student-focused	SGW DW SP	SGW DW SP	SGW DW SP	SGW DW SP	SGW DW SP
Notes					
Student-Teacher Interactions Teacher-led	IDQ ICQ IRQ	IDQ ICQ IRQ	IDQ ICQ IRQ	IDQ ICQ IRQ	IDQ ICQ IRQ
Student-Teacher Interactions Student-led	SQ SR PI	SQ SR PI	SQ SR PI	SQ SR PI	SQ SR PI
Notes:					
Instructional Technology	CB OP PP CL D DT M SI WEB	CB OP PP CL D DT M SI WEB	CB OP PP CL D DT M SI WEB	CB OP PP CL D DT M SI WEB	CB OP PP CL D DT M SI WEB
Notes:					
Potential Cognitive Demand	CNL PS CR	CNL PS CR	CNL PS CR	CNL PS CR	CNL PS CR
Notes:					

Post-Observation Field Notes

Note any over-arching observations about the class just observed or any specific incidents or activities that are worth elaborating upon. Also keeping in mind the purpose of the evaluation, make summative observations about the class. Finally, if a post-class survey such as the RTOP or Teaching Behaviors Inventory (TBI) is of interest in order to assess the efficacy of the class, administer the survey at this point.

Teaching Dimensions Observation Protocol (TDOP)

Citation for the instrument: Hora, M., & Ferrare, J.. (2014). The Teaching Dimensions Observation Protocol (TDOP) 2.0. Madison, WI: University of Wisconsin-Madison, Wisconsin Center for Education Research.

TDOP was largely adapted from Osthoff, E., Clune, W., Ferrare, J., Kretchmar, K., & White, P. (2009). Implementing immersion: Design, professional development, classroom enactment and learning effects of an extended science inquiry unit in an urban district. Madison: University of Wisconsin–Madison, Wisconsin Center for Educational Research.

Thanks to the National Science Foundation for providing support for work on the TDOP (DRL#0814724, DUE#1224624). Thanks to Amanda Oleson, Jana Bouwma-Gearhart, and other colleagues for providing assistance with this revision.

APPENDIX D: Field Notes for Research Lesson Observation

Date:

Name of Teacher:

Number of Students:

Classroom Configuration (Seating chart):

Lesson Type:

Observations	Comments

Additional Notes or Diagrams:

APPENDIX E: Lesson Plan Template

Science Lesson: **Grade: ______**

Date lesson will be taught:

Time lesson will begin:

Teacher Name:

Classroom #:

School name:

School address:

Special instructions:

Science Lesson

Grade: _____

Date:

Grade:

Period and Location:

Instructor:

I. Background information

A. Goal of the Lesson Study Group:

B. Narrative Overview of Background Information:

II. Unit Information

A. Name of the unit:

B. Goal(s) of the unit:

How this unit is related to the curriculum:

Instructional sequence for the unit:

Lesson Information

Name of the study lesson:

B. Goal(s) of the study lesson:

C. How this study lesson is related to the lesson study goal:

D. Process of the study lesson:

Steps of the lesson: learning activities and key questions (and time allocation)	Student activities/ expected student reactions or responses	Teacher's response to student reactions / Things to remember	Goals and Method(s) of evaluation	Notes

E. Evaluation

F. Appendix

APPENDIX F: Lesson Study Protocol

All lesson study tools developed by the Lesson Study Research Group are regularly revised and updated. To download latest versions of these documents, please go to: www.tc.columbia.edu/lessonstudy/tools.html.

Lesson Study Protocol

The following protocol guidelines are meant to facilitate the lesson observation and debriefing process. Although these guidelines are meant to make these activities more constructive and efficiently organized, they are not meant to minimize the critical or reflective nature of the feedback session[1].

Observing the lesson:

1. The observers, including the teachers who helped plan the lesson, should NOT interfere with the natural process of the lesson (e.g., by helping students with a problem). However, observers are permitted to circulate around the classroom during seatwork, as well as communicate with students for clarifying purposes only (e.g., if they could not clearly hear what a student was saying). Otherwise, observers should stand to the back and sides of the classroom.

2. It is a good idea for observers to note their observations on the lesson plan itself. This procedure will not only help observers focus on the goals and activities of the lesson, but also help them organize their feedback for later.

3. It is also a good idea for observers to distribute observations among themselves. For example, a few clusters of observers could watch assigned groups of students, another observer (usually one of the planning teachers) could keep time, etc. The teacher should

also prepare for this observation by distributing seating charts among the observers (if seating charts are not available, s/he could place nametags on each student), so that observers can conveniently refer to the children by name when discussing their observations and sharing their feedback.

<u>Preparing for the feedback session:</u>

1. Instead of discussing the lesson immediately after it has been taught, the entire group should take a break to relax and gather their thoughts.

2. The group who planned the lesson should assign roles among themselves in order to help keep the discussion focused and on track. These roles include: moderator/ facilitator (usually a member of the planning group besides the teacher who taught the lesson), timekeeper, and recorder(s).

3. The teachers who planned the lesson should sit together at the front of the room in panel formation during the feedback session. The purpose of this setup is to emphasize the idea that the entire group (not just the teacher who taught the lesson) is receiving the feedback.

Some of the suggestions described in this document were modeled by Japanese teachers at the Greenwich Japanese School, CT, and are also based on our work with U.S. teachers at Public School #2 in Paterson, NJ and at Community School District #2 in New York City.

Sonal Chokshi, Barbrina Ertle, Clea Fernandez, & Makoto Yoshida. Lesson Study Protocol ©2001, Lesson Study Research Group (lsrg@columbia.edu).

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<u>Suggestions for sharing feedback about the lessons:</u>

1. The moderator/ facilitator should begin the feedback session by (1) outlining the agenda for the discussion (e.g., "first we will hear from the teachers who planned the lesson, and then…"); and by (2) briefly introducing the goals of the planning group.
2. The teacher who taught the lesson should have the first opportunity to comment on his/ her reactions to the lesson, followed by the other planning group members. S/he should address what actually occurred during the lesson (e.g., what worked, what did not work, what could be changed about the lesson, etc.).
3. The planning teachers should also raise questions/issues that were raised during the planning sessions, and describe how these concerns were addressed by the instructional decisions they made for the study lesson. If the feedback session is after the second implementation of a study lesson, the planning members should clarify what changes were made between the two lessons, and how these changes related to the goals of the lesson.
4. The planning teachers should direct the observers to give them feedback that is related to the goals of the lesson. The observers can then share feedback about the lesson that helps the planning teachers address these goals. For example, observers could share their suggestions about how they might have done something differently in their own classes. Or, they could ask the planning teachers about their rationales for making certain decisions about the lesson (e.g., "Why did you choose those numbers for that problem?").

5. When observers share their feedback, they should begin on a positive note by thanking the teacher who taught the lesson and discussing what they liked about the lesson. Observers should then share critical feedback by supporting their statements with concrete evidence. For example, they could comment on specific observations from this particular lesson (e.g., "I saw student X do this…"), or make suggestions that draw upon their own experiences (e.g., "When I taught a similar lesson, I did (blank) differently because…").

6. Each observer should comment on a specific aspect of the lesson, and then give other observers the opportunity to comment on this point or related aspects of the lesson. This procedure prevents the feedback session from becoming dominated by one observer, and allows others to share their insights. If an observer would like to share something that is not being discussed at that point, s/he can write it down for later.

7. Similarly, the teacher(s) who planned/ taught the lesson should wait until a few comments about a particular aspect of a lesson have been received before responding to the observers. This waiting etiquette prevents the discussion from becoming a point-volleying session, and allows all participants to voice and absorb the feedback in a reflective manner. In addition, the moderator should be responsible for proactively keeping the debriefing session on track.

8. The timekeeper should remind the group when time is running short, so that the group can meaningfully wrap up their debriefing session. If an outside advisor is present, the feedback session should end with general comments from that person.

APPENDIX G: Lesson Plan for Research Lesson 1

Students will conduct a scientific investigation during which they will answer the following question:

What is the greenhouse effect and why do scientists often refer to some gasses as "greenhouse gasses" or global warming as the "greenhouse effect?"

Learning targets:

Primary: Students will understand how light and heat energy work in to sustain plant life in a greenhouse.

Secondary: Students will have a more thorough understanding of the greenhouse effect related to climate change.

Standards:

Design an investigation to demonstrate how different forms of energy release heat or light.

Design an experiment to investigate how different surfaces determine if light is reflected, refracted, or absorbed

In an effort to make these standards more relevant to students' lives, they will be participating in a series of investigations and research opportunities.

Before the lesson:

Students will read "Artic Sea Could Be Ice Free by 2050" by Thomas Sumner while making annotations noting connections, notes, or questions.

https://www.sciencenewsforstudents.org/article/arctic-sea-could-be-ice-free-2050 (I will omit paragraph 12, as it gives students too much information regarding greenhouse gasses and the greenhouse effect)

Students will then be invited to ask questions related to the over-arching question -- What is the greenhouse effect and why do scientists often refer to some gasses as "greenhouse gasses" or global warming as the "greenhouse effect?"

This will be whole group and teacher-guided.

What connections can you make to the article we just read?

What do we know about the word "greenhouse?"

The teacher will then discuss the fact that OCE has a greenhouse and we can investigate this further.

During the lesson:

The teacher will ask questions to activate schema and connect to previous lesson.

T: The purpose of our lesson today is to investigate the popular term "greenhouse effect" and the science behind it. We will learn what previously discussed science could be at play in a greenhouse and if this terminology is scientifically sound or not.

T: Let's talk about what we already know about greenhouses. What observations can we make without any scientific tools? In what ways do you predict the greenhouse is like the earth as a whole? What kinds of questions do we need to ask in order to figure this out?

The teacher will allow time for student feedback and discussion.

T: Ok, now it is time to get with our partners and do some investigating. Use the sheet provided to record your data for today, questions and connections.

The teacher will circulate with students to observe, conference and ask questions. Each set of partners should be charting data and making connections to the previous article in order to answer our focus question.

Concluding the lesson:

The teacher will call students back together to discuss observations and connections. Using the article read previously, today's data, and student prior knowledge regarding the earth's atmosphere, light and heat energy, students will likely conclude the terminology of the "greenhouse effect" is an accurate representation. As needed, the teacher will explain that the "greenhouse gasses" act much like the glass of a greenhouse. As the sun's rays enter our atmosphere, most continue on down to the planet's surface. When they hit the soil or surface waters, those rays release much of their energy as heat. Some of this heat then radiates back into space. However, several gases in Earth's atmosphere — such as carbon dioxide, methane and water vapor —work like a blanket to retain much of this heat. That helps to warm our atmosphere. The gases do this by absorbing the heat and radiating it back to Earth's surface.

Current weather Temperature / humidity / wind	Current greenhouse conditions Temperature/ humidity/ wind	Observations

Article	Scientific
Other	

Connections

Questions to further my understanding:
Thinking stems (Kaplan's)
I see a pattern in ________. Why does this occur?
I wonder if this pattern would continue over time?
What if _______ happened? How would _____ change?
The details in the article state _______________. How does _______________?

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My conclusions:

What is the greenhouse effect and why do scientists often refer to some gasses as "greenhouse gasses" or global warming as the "greenhouse effect?" Could this be an accurate scientific statement?

____
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APPENDIX H: Amended Lesson Plan for Research Lesson 2

Students will conduct a scientific investigation during which they will answer the following question:

Purpose: What is the greenhouse effect and why do scientists often refer to some gasses as "greenhouse gasses" or global warming as the "greenhouse effect?"

Learning targets:

Primary: Students will understand how light and heat energy work in to sustain plant life in a greenhouse.

Secondary: Students will have a more thorough understanding of the greenhouse effect related to climate change.

Standards:

Design an investigation to demonstrate how different forms of energy release heat or light.

Design an experiment to investigate how different surfaces determine if light is reflected, refracted, or absorbed

In an effort to make these standards more relevant to students' lives, they will be participating in a series of investigations and research opportunities.

Before the lesson:

Preteach vocab: The teacher will review tier 2 words that will be found in the article and in discussion about greenhouses.

Students will read "Artic Sea Could Be Ice Free by 2050" by Thomas Sumner while making annotations noting connections, notes, or questions.

https://www.sciencenewsforstudents.org/article/arctic-sea-could-be-ice-free-2050 (I will omit paragraph 12, as it gives students too much information regarding greenhouse gasses and the greenhouse effect)

Students will then be invited to ask questions related to the over-arching question -- What is the greenhouse effect and why do scientists often refer to some gasses as "greenhouse gasses" or global warming as the "greenhouse effect?"

This will be whole group and teacher-guided.

What connections can you make to the article we just read?

What do we know about the word "greenhouse?"

The teacher will then discuss the fact that OCE has a greenhouse and we can investigate this further.

During the lesson:

The teacher will ask questions to activate schema and connect to previous lesson.

T: The purpose of our lesson today is to investigate the popular term “greenhouse effect” and the science behind it. We will learn what previously discussed science could be at play in a greenhouse and if this terminology is scientifically sound or not.

T: Let’s talk about what we already know about greenhouses. What observations can we make without any scientific tools? In what ways do you predict the greenhouse is like the earth as a whole? What kinds of questions do we need to ask in order to figure this out?

Draw and label a greenhouse in relation to the earth (5min) What do the plants represent, etc.

Review Observation vs. Inference

The teacher will allow time for student feedback and discussion, and then write answers on a chart on the board.

Outside:

T: Ok, now it is time to get with our partners and do some investigating. Use the sheet provided to record your data for today, questions and connections.

The teacher will circulate with students to observe, conference and ask questions. Each set of partners should be charting data and making connections to the previous article in order to answer our focus question.

Concluding the lesson:

The teacher will call students back together to discuss observations and connections. Using the article read previously, today’s data, and student prior knowledge regarding the earth’s atmosphere, light and heat energy, students will likely conclude the terminology of the “greenhouse effect” is an accurate representation**. As needed, the teacher will explain that the “greenhouse gasses” act much like the glass of a greenhouse.** As the sun’s rays enter our atmosphere, most continue on down to the planet’s surface. When they hit the soil or surface waters, those rays release much of their energy as heat. Some of this heat then radiates back into space. However, several gases in Earth’s atmosphere — such as carbon dioxide, methane and water vapor —work like a blanket to retain much of this heat. That helps to warm our atmosphere. The gases do this by absorbing the heat and radiating it back to Earth’s surface.

Current weather Temperature / humidity / wind / Sunshine	Current greenhouse conditions Temperature/ humidity/ wind / Sunshine	Observations

Initial thoughts from the Article	Article	Scientific Investigation

Connections to other aspects of Science:

Questions to further my understanding:
Thinking stems (Kaplan's)

I see a pattern in ________. Why does this occur?

I wonder if this pattern would continue over time?

What if _________ happened? How would ___________ change?

The details in the article state as Carbon Dioxide builds up in the atmosphere, it strengthens the greenhouse effect. Why?

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My conclusions:

What is the greenhouse effect and why do scientists often refer to some gasses as "greenhouse gasses" or global warming as the "greenhouse effect?" Could this be an accurate scientific statement?

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APPENDIX I: District Approval Letter

TO: [redacted] MTSU Institutional Review Board [redacted]

FROM: Linda Gilbert, [redacted] hools [redacted]

SUBJECT: Support Letter for "Examining the Influence of Lesson Study on Elementary Science Teachers' Practice"

DATE: March 13, 2017

This letter is to accompany Chatoria Franklin's IRB Review Proposal "Examining the Influence of Lesson Study on Elementary Science Teachers' Practice." As [redacted] ty Schools, I am the only authorized person to give permission for [redacted] y Schools, thus I am the only person who can give consent to collect data and use that data in research-based publicatons that might result from the analysis of this data.

In order to potentially add to the body of knowledge concerning professional development and effective teaching and learning of mathematics, I authorize the demonstration and research lessons and subsequent debrief sessions which are a part of the "Examining the Influence of Lesson Study..." to be videotaped, coded, transcribed with pseudonyms, and analyzed in a manner consistent with the IRB application. Futhermore I authorize that participating teachers can submit samples of their students' work in conjuction with the demo and research lessons; all identifiers will be removed from the student work before submitting it to the researchers.

Please feel free to contact me if you have any questions or need further clarifications.

APPENDIX J: IRB Approval Letter

IRB
INSTITUTIONAL REVIEW BOARD
Office of Research Compliance,
010A Sam Ingram Building,
2269 Middle Tennessee Blvd
Murfreesboro, TN 37129

MIDDLE TENNESSEE STATE UNIVERSITY

IRBN001 - EXPEDITED PROTOCOL APPROVAL NOTICE

Monday, June 26, 2017

Principal Investigator	**Chatoria Kent Franklin** (Student)
Faculty Advisor	Angela T. Barlow & Cindi Smith-Walters
Co-Investigators	NONE
Investigator Email(s)	*cak2e@mtmail.mtsu.edu; angela.barlow@mtsu.edu; cindi-smith-walters@mtsu.edu*
Department	Mathematics and Science Education
Protocol Title	***Examining the influence of lesson study on elementary science teachers practice***
Protocol ID	**17-2185**

Dear Investigator(s),

The above identified research proposal has been reviewed by the MTSU Institutional Review Board (IRB) through the **EXPEDITED** mechanism under 45 CFR 46.110 and 21 CFR 56.110 within the category *(7) Research on individual or group characteristics or behavior* A summary of the IRB action and other particulars in regard to this protocol application is tabulated as shown below:

IRB Action	APPROVED for one year
Date of expiration	4/30/2018
Participant Size	10 (TEN)
Participant Pool	Elementary Science Teachers
Exceptions	Audio and video recording permitted
Restrictions	**1. Mandatory signed informed consent** **2. Identifiable information must be destroyed up on data entry.** **3. Voice recordings must be destroyed after data analysis.** **4. Schools only covered by the permission letter issued by Murfreesboro City Schools are allowed.**
Comments	Originally approved on 04.24.2017. The approval notice has been modified to an updated format (06.26.2017)

This protocol can be continued for up to THREE years (4/30/2020) by obtaining a continuation approval prior to 4/30/2018. Refer to the following schedule to plan your annual project reports and be aware that you may not receive a separate reminder to complete your continuing reviews. Failure in obtaining an approval for continuation will automatically result in cancellation of this protocol. Moreover, the completion of this study MUST be notified to the Office of Compliance by filing a final report in order to close-out the protocol.

IRBN001 Version 1.3 Revision Date 03.06.2016

Continuing Review Schedule:

Reporting Period	Requisition Deadline	IRB Comments
First year report	3/31/2018	TO BE COMPLETED
Second year report	3/31/2019	TO BE COMPLETED
Final report	3/31/2020	TO BE COMPLETED

Post-approval Protocol Amendments:

Date	Amendment(s)	IRB Comments
06.26.2017	1. Previously approved "observation protocol" is removed without prejudice. 2. A new version of the classroom observation protocol, "Reformed Teaching Observation Protocol," is approved.	NONE

The investigator(s) indicated in this notification should read and abide by all of the post-approval conditions imposed with this approval. Refer to the post-approval guidelines posted in the MTSU IRB's website. Any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918 within 48 hours of the incident. Amendments to this protocol must be approved by the IRB. Inclusion of new researchers must also be approved by the Office of Compliance before they begin to work on the project.

All of the research-related records, which include signed consent forms, investigator information and other documents related to the study, must be retained by the PI or the faculty advisor (if the PI is a student) at the secure location mentioned in the protocol application. The data storage must be maintained for at least three (3) years after study completion. Subsequently, the researcher may destroy the data in a manner that maintains confidentiality and anonymity. IRB reserves the right to modify, change or cancel the terms of this letter without prior notice. Be advised that IRB also reserves the right to inspect or audit your records if needed.

Sincerely,

Institutional Review Board
Middle Tennessee State University

Quick Links:

Click here for a detailed list of the post-approval responsibilities.
More information on expedited procedures can be found here.