UNDERSTANDING THE IMPACT OF A KIT-BASED SCIENCE RESOURCE ON TEACHERS’ ABILITY TO ENGAGE STUDENTS IN SCIENCE: AN INTERPRETATIVE PHENOMENOLOGICAL ANALYSIS

A doctoral thesis presented
by
Kristin Larsen
to
The School of Education

In partial fulfillment of the requirements for the degree of
Doctor of Education
in the field of
Education

College of Professional Studies
Northeastern University
Boston, Massachusetts
February, 2018
Abstract

The lack of time and attention dedicated to science at the elementary level is a problem that results in missed opportunities to engage students in science at an early age, potentially perpetuating the gender gap at the secondary, college, and career levels. There are many factors contributing to the lack of science education at the elementary level, including the provision of adequate materials and resources, instructional emphasis on subjects tied to high stakes testing, and the lack of content and pedagogical training provided for elementary teachers. This Interpretative Phenomenological Analysis explored the perspectives of nine teachers in grades Kindergarten through fifth with experience piloting a kit-based science resource, Full Option Science System (FOSS). This study employed Self-Determination Theory (SDT) as the theoretical framework as a means of examining engagement through the psychological needs for competence, autonomy, and relatedness. Results of the study indicate that participants observed a high level of student engagement, attributed primarily to the challenging, yet attainable hands-on approach of FOSS. Teacher confidence and enthusiasm for teaching science increased through the use of the kits and students reportedly attained a deep level of understanding of the scientific concepts. It cannot be conclusively stated that FOSS increased the teachers’ ability to engage students in science, as the students may have been engaged due to the novelty of hands-on aspect rather than the teacher’s competence in engaging them. As a result of this study, it is clear that providing teachers with high-quality instructional materials and resources, combined with training in pedagogical approach and content acquisition, can positively impact both teacher and student experiences with science.

Keywords: science education, elementary science, student engagement, teacher competence, kit-based resources, Self-Determination Theory (SDT), Full Option Science System (FOSS)
Acknowledgements

Briënna, we have made this journey together and I would not have finished without you. Our trips to Boston with Luke will always remain a favorite memory and representation of how this accomplishment was a shared family experience. Luuk and Neil, thank you for the emotional support and words of encouragement to keep going.

Mom and Dad, this achievement is possible thanks to your hard work and the sacrifices you have made. Thank you for instilling in us a strong work ethic and a drive to succeed, Aaron and I will always be grateful for what you have provided.

Dr. Nolan, thank you for the motivation to push through and for posing a challenge to strive to attain. This timeline would certainly not have been possible without your understanding of my goals and willingness to help me reach them. Dr. McNabb, thank you for your responsiveness and for your thoughtful suggestions along the way. To my external reader, Dr. Niemiec, I appreciate you responding to my initial inquiry for support and for the connection that we have made since. I look forward to working with you in the future.

To the Fairport Central School District, thank you for providing me the opportunity to conduct research in the district and for the support throughout. Thank you to the participants for sharing your experiences and for allowing me to learn from you.

This dissertation is dedicated to Luke.

My wish for you is to be curious, to explore, and to pursue your interests.

The world is yours, my amazing son. Harness the good in it, and be who you want to be!
# Table of Contents

**Abstract** ........................................................................................................................................... 2

**Acknowledgements** ........................................................................................................................... 3

**Chapter One: Introduction to the Study** ........................................................................................... 7
  - Statement of the Problem .................................................................................................................. 7
  - Significance of the Research Problem .............................................................................................. 9
  - Research Problem and Research Question ...................................................................................... 10
  - Definition of Key Terminology ....................................................................................................... 10
  - Theoretical Framework .................................................................................................................... 11

**Chapter Two: Literature Review** .................................................................................................... 26
  - Increasing Time and Attention Dedicated to Science ......................................................................... 27
    - Science Reform Agenda ................................................................................................................. 28
    - Next Generation Science Standards ............................................................................................ 29
    - Instructional Integration ................................................................................................................ 31
  - Improving Resources and Training .................................................................................................. 34
    - Elementary Teachers are not Content Area Experts .................................................................... 35
    - Educator Preparation .................................................................................................................... 36
    - Kit-Based Science Programs ....................................................................................................... 40
  - Engaging Elementary Students in Science ...................................................................................... 42
    - Benefits of Early Exposure to Science .......................................................................................... 43
    - The Gender Gap .......................................................................................................................... 49
    - Stereotypes .................................................................................................................................. 51
  - Conclusion ....................................................................................................................................... 54
Chapter Three: Research Design

Qualitative Research Approach

Interpretative Phenomenological Analysis

Participants

Procedures

Data Collection

Data Analysis

Criteria for Quality Qualitative Research

Chapter Four: Findings and Analysis

Teacher Confidence and Enthusiasm

Training

Content Knowledge

Readily Available Materials

Supportive Instructional Resources

Conclusions

Student Engagement

Optimal Challenge

Dialogue

Real World Connections

Conclusions

Hands-On Learning

Explore First

Challenging and Approachable Content
Chapter Five: Discussion and Implications for Practice ........................................... 106

Teacher Confidence and Enthusiasm ........................................................................ 107

Student Engagement ................................................................................................ 111

Hands-On Learning .................................................................................................. 115

Implications for Practice ............................................................................................ 119

Implications for Future Research .............................................................................. 123

Conclusion ................................................................................................................ 126

References .................................................................................................................. 129

Appendices ................................................................................................................. 146

Appendix A- Phase One Recruitment Email ................................................................. 146

Appendix B- Phase Two Recruitment Email (not utilized) ............................................. 147

Appendix C- Letter of Acceptance Template ............................................................... 148

Appendix D- Letter of Rejection to Study (not utilized) ............................................... 149

Appendix E- Informed Consent Document .................................................................. 150

Appendix F- Semi-Structured Interview Protocol ....................................................... 153

Appendix G- Transcript Review Template .................................................................... 156
Chapter One: Introduction to the Study

Motivation is an important factor in all aspects of education. Teachers strive to find what motivates students to learn, yet teachers must also be motivated to teach each subject effectively. Elementary teachers are not traditionally trained in science education methodology and districts often fail to provide elementary teachers with adequate resources to effectively teach science. In a self-contained elementary classroom, the structure of the day and allocation of instructional time dedicated to subject material is partially at the discretion of the teacher unless delineated specifically by the school district. A combination of the lack of training and resources may lead to less instructional time allocated to teaching science.

Humans exhibit intrinsic motivation when their needs for autonomy and competence are met (Niemiec & Ryan, 2009). In the Fairport Central School District, elementary teachers are provided with latitude in determining their instructional schedule as long as they meet minimum district requirements, such as the allocation of thirty minutes of science or social studies per day. It is important to understand teachers’ feelings of competency in teaching science as it can be a factor in their motivation to allocate time to science instruction. This Interpretive Phenomenological Analysis study seeks to understand how using a kit-based science program impacts teachers’ competence in engaging students in science. Knowledge generated is expected to inform local, regional, and national stakeholders on effective components of a widely used program in regard to teacher competency and student engagement.

Statement of the Problem

The minimal amount of instructional time and attention allocated to science, coupled with the lack of adequate resources and formal science training, result in a missed opportunity to engage elementary students in science. In New York State, science standards have not been
updated in over two decades until the recent adoption of the New York State Science Learning Standards (NYSSLS), which are based on the Next Generation Science Standards (NGSS). The combination of outdated standards and loss of instructional time has led to a lack of professional development as well as a lack of the allocation of new resources to effectively teach science at the elementary level. In the Fairport Central School District, elementary science textbooks are over fifteen years old. The science kits on loan through the local Board of Cooperative Educational Services (BOCES) are outdated and not aligned to the NGSS vision for science instruction.

The Next Generation Science Standards (NGSS Lead States, 2013) call for a new approach to science instruction. The multi-dimensional approach requires more hands-on science with engineering integration and less memorization of science facts. The adoption of the Next Generation Science Standards requires districts to change the way science instruction is delivered. However, even if school districts require more time allocated to elementary science instruction, the lack of adequate resources and formal training are barriers to consistently teaching science in a manner that engages students. Since the NGSS are relatively new, districts are left to either update curriculum on their own or look to curricular packages available for purchase. Delta Education’s Full Option Science System (FOSS), developed by the Lawrence Hall of Science at the University of California, Berkeley, is an example of a kit-based science program available for districts to purchase. The FOSS kit-based program contains all of the hands-on equipment, materials, and resources needed to conduct investigations aligned to the NGSS in one of the three major disciplines; Life Science, Physical Science, or Earth and Space Science. The kits include teacher manuals providing background knowledge on the scientific context of the content being taught, online instructional guides, prepared presentation slides that
are specified in a step-by-step manner should the teacher choose to use them, and student text resources to support the hands-on investigations. Fairport is entering into the third year of a pilot to assess the compatibility of the kits with district needs prior to purchase and implementation.

**Significance of the Research Problem**

The justification for research on the impact of adequate resources for elementary science instruction is based on the numerous federal reports over the past decade that call for an increase in science education, both in time and quality in an attempt to improve the STEM workforce in the United States (Holdren, Marrett, & Suresh, 2013; NRC, 2009). The National Research Council (2009) has emphasized the importance of science and engineering in American schools and developed the *Framework for K-12 Science Education* (NRC, 2012), upon which the Next Generation Science Standards were developed. Nationally, there is a lack of time dedicated to science instruction at the elementary level; approximately eighty percent less time than English Language Arts (ELA) and less than half the amount of time spent on mathematics (Blank, 2013). There are a variety of reasons for the lack of instructional time on science at the elementary level, including the focus on accountability for high stakes test results in ELA and mathematics, which leads to a narrowing of instructional time to tested subjects (Au, 2007). However, the lack of emphasis on science may perpetuate the shortage of qualified workers needed to fill STEM fields in the future and continue to widen achievement gaps among female students and students of color (NRC, 2011).

A primary objective of the NGSS is to change the current structure of science to incorporate more hands-on and inquiry-based methodology, similar to the actual work of a scientist or engineer. It is important to engage students in science at the elementary level because early and repeated exposure to high-quality science and engineering instruction has been linked
to a potential increase in students’ sense of competence, interest, confidence, and attitudes regarding science and engineering (Capobianco, Yu, & French, 2015). Introducing a kit-based program to elementary educators meets the reform agenda by incorporating more hands-on science instruction that is aligned to the NGSS, providing materials and resources aimed at improving elementary science instruction, and seeks to engage students and teachers in science. The FOSS kits were recently aligned to the NGSS and there are currently no studies that examine the impact of the NGSS version of the FOSS kits on teachers’ competency in engaging students in science, thus supporting the need for this study.

**Research Problem and Research Question**

The minimal amount of instructional time and attention as well as the lack of adequate resources and training leads to inconsistently engaging students in science. The national reform agenda calls for an increased focus on science at the elementary level, which may also lead to enhanced student interest in science. A kit-based program such as FOSS provides teachers with materials, resources, and scientific background knowledge to teach science at the elementary level. The purpose of this study is to understand how using the FOSS kits impacts teachers’ ability to engage students in science. The research question that this study will seek to answer is:

1) How do teachers describe their understanding of the impact of FOSS on their ability to engage students in science?

**Definition of Key Terminology**

**Kit-Based Program**- A pre-packaged kit including science materials and resources to conduct hands-on investigations.

**Next Generation Science Standards**- Kindergarten through Twelfth grade curricular standards that set expectations of what students are required to know at each grade level. The standards are
available for adoption by each state in the country. New York State adopted a version with slight modification in December, 2016.

**Theoretical Framework**

Better understanding how the FOSS kits impact teachers’ ability to engage students in science will be viewed through the lens of Self-Determination Theory (SDT) (Deci & Ryan, 1985). SDT was chosen as the framework for this study because understanding the impact of district provided resources on teacher motivation to teach science is critical in a district where teachers have some flexibility in allocating instructional time dedicated to science. Exploring teacher perceptions of how the FOSS kits impacted their ability to teach science will draw from the basic psychological needs for competence and autonomy. Motivation is a key factor in facilitating student engagement and contributes to the engagement or lack thereof observed in students. SDT has been widely used in the educational field and serves as an appropriate foundation for the research question addressed in this study. This section will include an overview of the theory, a description of the primary tenets of SDT, the six mini-theories of SDT, and an examination of critiques. A description of the most pertinent aspects of SDT that apply to the study will follow as will a rationale for using SDT to address the problem of practice.

Fundamental to Self-Determination Theory is the assumption that human beings are social organisms that are influenced by their environment. In SDT, whether one’s behaviors are controlled or autonomous is highly dependent on environmental social factors that will either support or thwart a person’s ability to thrive (Ryan & Deci, 2017). The three developmental needs obtained from the social environment are that of competence, autonomy, and relatedness. Each are influential factors in determining one’s motivation. Additionally, one’s interpretation of the causality of the environmental factors, controlled versus autonomous, plays a role in the
resulting behavior (Gagne & Deci, 2005). SDT examines types of motivation and the intrinsic and extrinsic factors that influence the behavior rather than attempting to assess the amount of motivation a person possesses (Deci & Ryan, 2008b).

Motivation exists on a continuum from amotivation to extrinsic motivation to intrinsic motivation. Extrinsic motivation is broken into four categories on the continuum; external regulation, introjected regulation, identified regulation, and integrated regulation. Extrinsic motivation in the external and introjected regulation categories result in less internalization of the regulation, thus leading to compliant behavior or behavior that is contingent upon an external factor rather than behavior that is self-determined. On the other hand, extrinsic motivation in the identified or integrated regulation categories result in a perceived internal causality, meaning that the behaviors are, to an extent, internalized as valuable and emanating from oneself.

The more highly satisfied the basic needs for competence, autonomy, and relatedness are met, combined with the perceived level of autonomy versus control in the regulatory style and the interpretation of causality, the more integrated the motivation for a behavior becomes (Ryan & Deci, 2017). For example, if a person perceives the causality of a regulation to be imposed upon them and complies with that regulation to gain approval despite the minimal sense of competence, autonomy, or relatedness attained, it will result in a failure to identify with that value. Integrated internalization occurs when a person identifies with a regulation, internalizes it as a sense of one’s own self, and therefore, results in self-determined behavior (Deci, Eghrari, Patrick, & Leone 1994).

**Primary Tenets of Self-Determination Theory**

Self-determination theory consists of three primary needs that are indicators of optimal motivation; competence, autonomy, and relatedness. The social world influences human
perceptions of what and who they should be. The need for competence, relatedness, and autonomy play a role in how one perceives themselves as situated in a particular environment, which has an impact on their motivation. In the educational setting, teachers consistently attempt to motivate students to endorse certain behaviors as supervisors do to employees. Prior to embarking on a study aimed at better understanding motivational factors, it is important to become more familiar with the primary tenets of SDT and the six SDT mini-theories associated with it.

**Competence**

Ryan and Deci (2017) define competence as “our basic need to feel effectance and mastery” and go on to say that feeling effective in one’s environment is an important factor in one’s motives for engaging in activities. Competence is a psychological need that can be diminished easily in light of critical feedback or difficult challenges. Compared to no feedback, positive feedback has a positive impact on intrinsic motivation, whereas negative feedback has a negative impact on intrinsic motivation. However, to have a positive impact on intrinsic motivation, one must feel responsible for their performance which elicited the positive feedback. Perceived competence can increase intrinsic or extrinsic motivation in a person, however, a sense of autonomy must also be present in order to increase intrinsic motivation (Deci & Ryan, 2000b).

**Autonomy**

Autonomy refers to “the need to self-regulate one’s experiences and actions” (Ryan & Deci, 2017). Humans possess a need for personal autonomy, meaning that their behaviors are initiated by themselves and not due to external influences (Deci & Flaste, 1995). Autonomy refers to behavior that is voluntary or self-initiated rather than influenced by external forces. When acting autonomously, one is acting in coherence with his or her own values and not
coerced by external forces (Ryan & Deci, 2017). Rewards, threats, deadlines, and evaluations are proven to have diminishing effects on intrinsic motivation compared to choice and acknowledging one’s feelings, which may improve intrinsic motivation and confidence (Deci & Ryan, 2000). Autonomy supportive, as opposed to autonomy thwarting or controlling environments, produce more positive outcomes.

**Relatedness**

Relatedness refers to feeling connected socially, such as when cared for by others or through a sense of belonging to or contributing to others (Ryan & Deci, 2017). A sense of relatedness occurs through communication and interactions with others, either being inside a social group or outside of the group, therefore sensing relatedness or not (Deci & Ryan, 1985). SDT posits that humans function largely as a result of their surroundings and that their behaviors and motivation are driven by the manner in which external influences are internalized. While relatedness is considered one of the basic social developmental needs according to SDT, the needs for autonomy and competence have a more influential role on intrinsic motivation.

**Mini-Theories of Self-Determination Theory**

Competence, autonomy, and relatedness are essential to facilitate optimal functioning in the areas of growth, social development and personal well-being (Deci et al., 1994). A central understanding of Self-Determination Theory is that human beings are proactive creatures whose intrinsic functioning depends largely on the social context in which they are exposed (Deci et al., 1994). The social contexts that influence competence, autonomy, and relatedness are examined more closely in the six mini-theories of SDT, some relying more heavily on one of more of the three primary tenets.

**Cognitive Evaluation Theory**
Cognitive Evaluation Theory (CET) focuses primarily on competence and autonomy and was initially introduced as a subtheory aimed at identifying social and environmental factors that support, rather than diminish, intrinsic motivation (Ryan & Deci, 2000b). Relevant to teacher and student sense of competence, CET argues that social events and feedback on performance play a role in one’s intrinsic motivation, particularly that positive interactions and feedback lead to a sense of perceived competence. However, a sense of autonomy supportiveness, rather than autonomy control is another critical factor in determining one’s sense of motivation. Therefore, one must feel a perceived sense of competence and elicit self-determined behavior in order for intrinsic motivation to exist (Ryan & Deci, 2000b). Important to note about CET is that it will only apply to a study if there is an inherent intrinsic motivation present (Ryan & Deci, 2000b). CET may be used in the educational setting or in the workplace to examine teacher and student responses to autonomy supportive versus autonomy controlling environments.

Organismic Integration Theory

Unlike CET, which focused on intrinsic motivation, Organismic Integration Theory (OIT) looks at extrinsic motivation and how one internalizes the factors that influence the type of motivation. OIT concentrates primarily on relatedness, or the need to belong or feel connected to others. According to Ryan and Deci (2000b), this can mean that one feels, or wants to feel, connected to a person or social group. Competence also comes into play with OIT as humans tend to gravitate to activities in which they perceive themselves to be somewhat competent. Therefore, with OIT, extrinsic motivational factors become more internalized if one feels like they belong, or want to belong, to a group and if they feel competent with the activities of that group. OIT posits that motivational regulation falls into four categories ranging from the least internalized to the most; external, introjected, identified, and integrated (Ryan & Deci, 2017).
Simply put, extrinsic motivation can produce various degrees of self-determination rather than either producing motivated behaviors or failing to produce motivated behaviors. It is important to note that while extrinsically motivated behaviors initially need external prompting, they may result in internalization of that behavior as one ends up finding the activity or task intrinsically motivating (Ryan & Deci, 2000a).

**Causality Orientations Theory**

Causality Orientations Theory (COT) attends primarily to the need for autonomy and how one perceives their environment. Causality orientations refer to ways in which one takes in and accounts for information in their environment, which influences motivation. One who perceives his or her environment to be autonomy supportive see the option of choice and self-determination as opposed to those that view factors in their environment as autonomy controlling (Ryan & Deci, 2017). The manner in which a person views the causality of the environmental factors contributes to people behaving differently even in the same social contexts, the behavior is a result of their interpretation and internalization of the social context.

**Basic Psychological Needs Theory**

Rather than focusing on how competence, autonomy, and relatedness contribute to intrinsic or internalization of extrinsic motivation, Basic Psychological Needs Theory (BPNT) posits that depending on how well or poorly one’s basic psychological needs are met has a direct impact on one’s well-being or its opposite, ill-being (Ryan & Deci, 2017). Each of the basic needs is accounted for in this mini-theory and the degree to which each is satisfactorily met plays a role in improving or declining well-being, or one’s wellness. An enhanced sense of wellness contributes to better overall functioning, personal growth and development, and are increased in autonomy supportive environments (Ryan & Deci, 2017).
Goals Contents Theory

Goals Contents Theory (GCT) is different from the previous mini-theories in that it explores “what” one’s behaviors are motivated by and how the societal factors contributing to “why” one behaves in a certain way. Ryan and Deci (2017) stated that the mini-theory was developed based on research indicating that goals are pursued for one of two broad reasons; extrinsic aspirations and intrinsic aspirations. Essentially, goal pursuits founded on extrinsic aspirations such as wealth tend to be more autonomy thwarting and, thus less internalized because they do not fully satisfy the needs for competence, autonomy, and relatedness. Intrinsic goal aspirations, such as personal development, tend to be more autonomy supportive and more greatly satisfy the basic developmental needs.

Relationships Motivation Theory

Relationships Motivation Theory (RMT) deals primarily on the need for relatedness, specifically the desire to have close relationships. Within the relationship, the degree of satisfaction of the needs for competence, autonomy, and relatedness determine the authenticity and wellness of the relationship (Ryan & Deci, 2017). Humans need for relatedness provides the intrinsic motivation to seek out others. The degree of the quality of the relationship depends on each person’s autonomous motivation to engage in the relationship and provide each other an autonomy supportive environment (Ryan & Deci, 2017).

Critics of Self Determination Theory

An early criticism of SDT revolved around the concept of the impact of reward on intrinsic motivation (Cameron & Pierce, 1994; Eisenberger & Cameron 1996). The argument of these critics was that rewards, based on behavior theory, have positive effects and that negative effects can be accounted for and diminished. Additionally, that the notion of extrinsic rewards
negatively affecting intrinsic motivation, such as rewarding children with prizes for reading, was a myth and that negative changes in intrinsic motivation could be attributed to Romanticism. Critical Evaluative Theory is the primary subject of Eisenberger and Cameron’s (1996) objection, stating that it is ambiguous and lacking the ability to pinpoint why a decrease in intrinsic motivation occurred in empirical studies. Ryan and Deci (1996) responded to the Cameron and Pierce (1994) article with a scathing criticism of the use of literature to support their claims and posited that the resistance to SDT originates from the juxtaposition of behavioral science theories and the psychologically based theory of SDT. Deci, Koestner, & Ryan (1999) countered the arguments of Eisenberger and Cameron (1996) in a meta-analysis of 128 studies that examined intrinsic and extrinsic motivation and concluded that rewards can certainly help to provide an appearance of motivation as they are widely used to control behavior, however, overall they tend to diminish one’s self-determined behaviors, even toward interesting activities.

Carver and Scheier (2000) drafted an article questioning the clarity of many of the components of SDT. One of the primary concerns of Carver and Scheier is that the three fundamental needs are not equivalent in weight, and in fact, that the need for competence actually hinges on the need for autonomy. They propose that perhaps a hierarchical model be utilized when determining the influence of the three needs. Additionally, Carver and Scheier take issue with several points including but not limited to; a) the word autonomy is used in a different manner than the definition in everyday language; b) SDT assumes that autonomy, in the sense of free will, is actually possible and assert that perhaps the perception of autonomy is more likely than the existence of autonomy and; c) lack of clarity around the definition of true self, specifically how to fulfill the true self.
Lee (2017) takes issue with supposition that as long as one’s behavior emanates from one’s self it can be considered autonomous. Lee expresses concern with the misconception that autonomy equates to independence and control and proposes that as a dangerous misconception when working with a population of language learners. Lee acknowledges that Ryan and Deci (2009) made clear the distinction between independence and autonomy, however argues that researchers need to be careful when reporting on autonomy for language learners as to not make assumptions on the correlation between autonomy and independence.

**Rationale for Utilizing Self Determination Theory**

**SDT in Education**

Deci, Vallerand, Pelletier, and Ryan (1991) emphasized that the critical features in an excellent education are conceptual understanding and the flexible use of knowledge, not merely the acquisition and retention of facts. Fast forward to the New York State adoption of the Next Generation Science Standards in 2016 and the sentiments expressed in 1991 are echoed in the vision for the future of science education. Infants are naturally inquisitive and eagerly seek to explore the world around them; they learn much through social responsiveness (Ryan & Deci, 2017). Hands-on, inquiry-based science instruction compliments the inquisitive nature of children to question and explore.

Educators consistently strive to find what motivates children in their classrooms. Some children are more eager and intrinsically motivated to learn and some need more prompting and extrinsic motivational factors. SDT based studies have shown that autonomy supportive teachers and autonomy supportive classrooms have positive impacts on student learning, achievement, motivation and students are more inclined to retain their curiosity (Deci & Ryan, 2008a; Su &
Reeve, 2011). Similarly, autonomy supportive workplaces have shown to increase employee performance, persistence, and creativity (Deci & Ryan, 2008a).

Teachers often impose external regulators thinking that they will enhance learning, however, even if students’ feel competent in their ability to perform a task they will not maintain intrinsic motivation for that task unless they also feel a sense of autonomy (Niemiec & Ryan, 2009). In essence, controlling environments thwart intrinsic motivation. The types of tasks as well as the way they are introduced impact student motivation. Niemiec and Ryan (2009) suggest that teachers can support student autonomy by; a) minimizing evaluative pressure; b) minimizing any sense of coercion to perform the activity and; c) maximizing students’ perception of choice to engage in the activity. Additionally, they state that teachers can support student competence by; a) introducing optimally challenging learning activities, b) providing appropriate tools and feedback, and; c) emphasizing students’ effectance rather than evaluation.

Student engagement refers to a student’s investment in a task at hand. Engaging students in schoolwork is important as the level of engagement reflects one’s motivation and contributes to learning and development (Reeve, Jang, Carrell, Jeon, & Barch, 2004). Engagement in a learning activity requires the student to intentionally act on participation in the activity. In the classroom setting, student participation can emanate from an internal causality or from external pressure from the teacher or social pressure in the classroom environment, the latter reflecting a lower sense of autonomy. The results of a study grounded in SDT by Reeve and Jang (2006) indicate that teachers can foster an autonomy supportive environment by incorporating various strategies into their teaching such as providing independent work time, offering praise for improvement, giving hints when students are stuck, and acknowledging student’s perspective and experiences. In a follow up study on why teachers adopt controlling environments, Reeve
(2009) identified five additional instructional strategies that teachers can employ to become more autonomy supportive; a) nurture inner motivational resources; b) provide explanatory rationales; c) utilize noncontrolling language; d) exhibit patience and provide a self-paced learning environment, and; e) permit negative expressions of affect from students.

Educational leaders must ensure that they support teachers’ sense of autonomy, competence, and relatedness. In the era of the Common Core State Standards and teacher accountability on high stakes testing, teachers have an enormous amount of pressure on them to perform. The more controlled teachers feel, the more controlling they tend to be with their students (Niemiec & Ryan, 2009). Gagne and Deci (2005) argue that work climates that promote the needs for autonomy, competence, and relatedness enhance intrinsic motivation and the internalization of extrinsic motivation, with autonomy support being the most important factor. When supervisors impose curricular restrictions and place pressure on teachers for accountability, teachers become more controlling toward their students (Pelletier, Seguin-Levesque, & Legault, 2002).

**Needs and Mini-Theory Rationale**

SDT has been widely used in the field of education and is an appropriate theoretical framework for this study. The critiques of the theory are based on variables that were not directly examined in the study, particularly the aspect of the impact of rewards. While many of the empirical studies utilizing SDT are conducted in a quantitative format, a qualitative approach is appropriate given the research questions and intention of better understanding teacher competence and motivational factors. The basic developmental needs of competence and autonomy as defined in SDT was the focus of the study. The research question sought to better understand how the kits impact teacher ability to engage students and how they impact their
sense of competence in teaching science. With competence clearly positioned at the forefront of the research questions, autonomy is an important component to understanding both teacher motivation to teach science and student engagement in science. While the three basic needs are ever-present, the need for relatedness does not fit as a central theme to be examined in the scope of this study.

Causality Orientations Theory would not be an appropriate mini-theory to use as the pilot teachers are voluntary. The data could include a sense of whether or not participants volunteered based on autonomy or control orientations, however the COT mini-theory would be better utilized in a study where implementation of the kits was mandatory. The study does not seek to determine participant psychological health or wellness, therefore BPNT is not an appropriate mini-theory. Similarly, GCT nor RMT will be utilized as the study does not examine goal setting or relationship development of the participants.

CET is tempting to use as a basis for this study as it focuses on competence and autonomy, however the premise suggests that intrinsic motivation must be present in order to utilize this mini-theory. It is possible that research may reveal an underlying intrinsic motivation present for teachers piloting FOSS, however it cannot be assumed that intrinsic motivation is present for all members of the participant pool. OIT moves beyond intrinsic motivation to better understand the types of extrinsic motivation and how conditions are internalized. OIT also examines the social factors that support or thwart internalization, which impact how one approaches their social environment. While it would not be appropriate to utilize CET singularly, the combination of components from both CET and OIT in a qualitative study would allow for an understanding of the participants sense of competence, autonomous engagement in the behavior, as well as provide a platform to nest student engagement.
Application to the Study

The extent to which the basic social developmental needs of competence, autonomy, and relatedness are met determine the type of environment; autonomy supportive, effectance supporting, or relationally supportive. Autonomy supportive environments offer choice, competence supportive environments offer structure and positive feedback, and relatedness supportive environments offer the care of others (Ryan & Deci, 2017). While the presence of all three needs are influential factors in determining one’s motivation, for the purpose of this study, teachers’ sense of competence in their ability to engage students in science was the focus, thus a focus on the degree of effectance support in regard to teachers’ sense of confidence in teaching science. Additionally, in obtaining data from interviews to better understand the impact of FOSS on their ability to engage students in science, teacher responses informed motivational factors they observe as contributing to student engagement.

SDT served as an appropriate framework for a study aimed at understanding the impact of FOSS on teachers’ ability to engage students in science because engagement and motivation are closely aligned. Additionally, understanding the change in teachers’ sense of confidence in teaching science as a result of piloting FOSS, the need for competence as a component of motivation as outlined in SDT is applicable. Elementary teachers are required to teach a minimum of thirty minutes of science or social studies per day in the Fairport Central School District. It is critical to understand their sense of competence with teaching a technical subject in which the majority of the teachers have no formal training to better inform future instructional decisions. The FOSS kits provide resources and materials for the teachers, yet it is important to know if the use of the materials and resources play a role in teachers’ sense of competence in teaching science.
Conclusion

Self-Determination Theory is a commonly utilized theory to better understand motivation. Understanding factors that impact teacher and student motivation is significant for educators and educational leaders as teacher and student motivation impacts learning and achievement. Teachers and supervisors wish to tap into intrinsic motivation as well as the internalization of external motivation as it yields high-quality performance and learning. Certain types of extrinsic motivation can impede performance and high quality learning, however extrinsic motivation can also lead to internalized behaviors via personal acceptance of regulations as one’s own. The education and workplace settings do not always include intrinsically motivating tasks, therefore, it is necessary to rely on enhancing types of extrinsic motivation that promote involved, active participation (Ryan & Deci, 2000a). SDT was used as the framework to better understand the impact that FOSS kits have on teachers’ ability to engage students in science as well as the impact that they have on teacher competence in teaching science.

SDT was chosen as the theoretical framework due to its broad application in various fields. This study sought to understand teachers’ perceptions of student engagement as well as teacher competence. Although teachers are employed in an education setting, distinguishing them as employees in a workplace with various external pressures is a necessary component of the study. Teacher response to and the type of motivation elicited from the external pressures has an impact on classroom instruction, and thus the students in the classroom. SDT allows for both an examination of their perceptions of student engagement and their sense of competence for engaging in an activity, teaching science. The literature review that follows will outline in more detail how the minimal instructional time and attention dedicated to science coupled with the
lack of adequate resources and formal science training result in a missed opportunity to engage elementary students in science.
Chapter Two: Literature Review

Elementary science education should strive to engage students through hands-on, conceptual based exploration of scientific phenomena. Piquing young children’s’ interest in science can have lasting effects that impact their future. Unfortunately, elementary science education tends to receive limited instructional time and the time that is allocated to elementary science may not be supported with high quality resources. The topic of this literature review focuses on the lack of adequate resources and formal science training that results in elementary teachers inconsistently teaching science in a manner that engages students in science. The context of the review is situated in understanding the common experiences of elementary teachers who piloted the FOSS kit-based science program in the Fairport Central School District. Specifically, the study seeks to understand how teachers describe their understanding of the impact of FOSS on their ability to engage students in science as well as the impact the kits have on their sense of confidence in teaching science.

Research on the impact of adequate resources for elementary science instruction is a significant issue in the educational setting as there has been a national call for the improvement of science education in the United States. Some factors contributing to the need for improvement include a lack of time dedicated to science instruction at the elementary level as well as a lack of training and resources available to teachers. The underlying problem is that the minimal instructional time and attention allocated, in addition to the lack of adequate resources and formal science training, results in a missed opportunity to engage elementary students in science. It is important to note that the Next Generation Science Standards (NGSS) explicitly embed engineering into the science standards at all grade levels. This is a new concept at the elementary level and, therefore the literature review will refer to both science and engineering throughout.
The review of literature is organized in a manner that explores three streams; increasing time and attention dedicated to science, improving instructional resources and teacher training, and engaging elementary students in science. Changing the current status of science education by increasing time and attention dedicated to science is justified by research and is supported by the science reform agenda. The new science standards set the foundation for this change and provide an opportunity for instructional integration. Following the justification for change, improving instructional resources and teacher training will be viewed through the lenses of teacher training in science content, educator preparation, and kit-based science programs. The literature review will conclude with a section on engaging elementary students in science by examining the benefits of early exposure to science, the gender gap, and mitigating the stereotypes.

**Increasing Time and Attention Dedicated to Science**

The lack of science and engineering instruction in the elementary classroom is a significant problem in American schools. Since 2000, the instructional time spent on elementary science education has declined while time on ELA and mathematics has increased (Blank, 2013). There are several reasons that science and engineering practices are not taught in elementary schools, including; a hyper focus on subjects correlated to high stakes testing (Judson, 2013), outdated standards, and limited time in the instructional day to focus on four content areas. Some problems associated with the limited amount of time and attention dedicated to science include; fewer students are selecting Science, Technology, Engineering, and Mathematics (STEM) fields as majors in college, perpetuation of the STEM gender gap, and failure to increase awareness and interest in STEM. Each of these constraints can be remedied to improve science instruction. The federal reform agenda spurred the development of the Next Generation Science Standards
(NGSS Lead States, 2013), yet does not provide relief to individual classroom teachers struggling to teach four core subjects per day. Integration of engineering with science and science with other core areas may help alleviate the burden and draw more attention to the benefits of science education.

**Science Reform Agenda**

There is an apparent lack of interest in STEM fields, based on the low number of college graduates entering the field. The United States could experience a crisis as the country faces a deficit in the number of engineers and highly skilled technical workers available to fill positions (Marulcu, 2014; Nugent, Kunz, Rilett, & Jones, 2010). Women are generally underrepresented in science and engineering, earning fewer degrees in those areas than male counterparts, although biological sciences are an area that attracts more women than the other fields of science. In 2000, 16% of Ph.D. degrees were earned by women, of those 24% were in physical sciences and 43% in biological sciences (Miller, Blessing, & Schwartz, 2007). Given the concerning trends in employment in science and engineering fields, there have been numerous federal reports in the past decade calling for an increase in STEM education.

Multiple reports call for improvement in public education in order to increase awareness and interest in engineering, performance in science, and increased competitiveness in STEM fields worldwide (NRC, 2009). Innovative instructional methods that help develop solid math and science learners (Carnegie Foundation, 2009) and provide effective approaches in STEM education (NRC, 2011) are needed. In 2012 the NRC released a report titled, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, which includes best practice approaches intended to provide a rationale for improving science instruction. The Framework calls for American science education to equip students with a better understanding of
science and engineering practices, to spark an interest in science through hands-on experimentation, and ultimately lead to a more competitive field due to an increase in scientific thinkers (NRC, 2012). The NGSS (NGSS Lead States, 2013) were created from the 2012 Framework and are available for adoption by individual states. New York State adopted the New York State version of the standards in December of 2016.

The United States government is actively promoting Science, Technology, Engineering and Mathematics in American schools so as to remain competitive with the rest of the world (Holdren, Marrett, & Suresh, 2013). STEM is a broad field that encompasses Science, Technology, Engineering, and Mathematics as well as several sub-disciplines in each field. Each field could be examined separately to identify methods for improving instruction and outcomes. Given the wide range of disciplines covered in STEM, the research for this study will focus specifically on science and engineering. Engineering is a significant component of the Next Generation Science Standards (2013), which call for engineering integration in science instruction and thus engineering would be inappropriate to leave out of a literature review on science education.

Next Generation Science Standards

Following the Release of the Next Generation Science Standards, the National Research Council conducted a formal review of the standards to ensure that they adhered to the vision and recommendations of the Framework. It was determined that the standards adhere to the content and structure recommended in the Framework (NGSS Lead States, 2013). The executive summary of the NGSS emphasize that the structure of the standards embrace a new approach to science instruction through the integration of content, practices, and crosscutting concepts. This
approach is aligned to the actual practice of scientists and engineers. Each science concept progresses across the K-12 standards and is revisited with increasing complexity.

A key understanding in teaching the new science standards is that in the real-world science and engineering involve a combination of content and practice, not one isolated from the other. The Framework (NRC, 2012) recommended the integration of content, practice, and concepts in order to provide students; a) with context for the content learned; b) an understanding of how science knowledge is attained and; c) with an understanding of how science concepts transcend across disciplines. The standards were written with the intention of allowing states and local districts discretion in implementation and curriculum design, providing flexibility to develop curriculum unique to each district (NGSS Lead States, 2013). New York State has adopted the standards with the same intention of allowing districts to make local instructional decisions in regard to resources and implementation.

The Next Generation Science Standards are broken into three primary components; Disciplinary Core Ideas (DCI’s), Science and Engineering Practices (SEP’s), and Crosscutting Concepts (CC’s). Each component is also broken into respective categories that are replicated in each grade level. There are four subjects incorporated into the DCI’s; Physical Sciences, Life Sciences, Earth and Space Sciences, and Engineering Design. The eight SEP’s and seven CC’s are addressed in each grade level and provide students with experiences that allow them to behave as scientists and engineers and explore how concepts overlap across disciplines. Engineering is clearly integrated into the new science standards. While the new standards are intended to promote scientific thinking and exploration, elementary teachers may have difficulty implementing the standards given time constraints in their daily schedules. Cross curricular
integration could help remedy some of the barriers currently preventing high quality science instruction at the elementary level.

**Instructional Integration**

Science and engineering practices at the elementary level will look quite different than at the secondary and post-secondary levels. Science and engineering instruction can be integrated with core subject areas, particularly in the self-contained elementary classroom setting. The reading, writing, modeling, and reflection that accompanies hands-on science can be integrated into time traditionally reserved for English Language Arts (ELA) and mathematics. The NRC (2014) report provides insight into the benefits of integrated STEM education. It also stresses the need for both content and pedagogical support for elementary teachers and flexibility in scheduling. Johnson, Peters-Burton, and Moore (2015) provide a comprehensive plan for an integrated STEM instructional model that includes providing a motivating learning environment, incorporating engineering challenges, providing students with an opportunity to redesign and learn from failure, and the incorporation of all core areas into classroom instruction. McNew-Birren and van den Kieboom (2017) emphasize the importance of structuring every lesson around a conceptual goal to develop deep conceptual understanding of content in inquiry-based instruction.

Engineering instruction may seem foreign to the elementary classroom, however engineering at the elementary level is suitable for all students and grade levels. Engineering in an elementary classroom involves a process of design that is situated in a real-life scenario with a given set of constraints. Design is iterative and educators must allow students the opportunity to design and redesign, create and recreate their work based on information learned through each preceding iteration and through collaboration and communication with classmates. Engineering
provides a platform, nested in a real life and engaging scenario, that promotes student-directed inquiry and evidence based justifications of student work while applying the learning of science and math (Roehrig, Wang, Moore, & Park, 2008) and developing problem-solving and communication skills through scientific discourse.

The collaborative processes of science investigations and engineering design promote the frequent use of scientific discourse as students engage in conversations about their work with classmates. The more students talk about science, using scientific terminology, the more comfortable they become with using the language. Literacy does not solely refer to reading and writing (Norris & Phillips, 2003), scientific literacy can begin to develop early with exposure to science. Engineering problems, placed in a real-world context, incorporate aspects of social studies as well as the literacy skills of reading, writing, listening and speaking and can also enhance science content learning (Bethke Wendell & Rogers, 2013). Engineering provides a backdrop for learning science, mathematics, and technology (Moore, et al., 2014). Students apply their discourse with peers into written language in the form of words or drawings. Through instructional integration, students can learn to value evidence and use it to explain scientific phenomena, which promotes scientific learning and understanding (Gilles & Nichols, 2015).

Not only can science and engineering integration provide a more equitable distribution of instructional time across content areas, but integration with other content areas is necessary in teaching engineering as it is not, nor should it be, an isolated subject (Moore, Tank, Glancy, & Kersten, 2015). Guzey, Tank, Wang, Roehrig, and Moore (2014) state, “without science and mathematics connections, engineering activities can become isolated, unrelated activities that depict engineering as tinkering or craft projects” (p. 141). Engineering is best taught via integration with other content areas. This is helpful to elementary teachers who struggle to fit in
all of the content areas each day. Implementing engineering projects can alleviate the time restraints felt by many teachers in that it can allow teachers to demonstrate how multiple disciplines are needed to solve an engineering problem. When working on an engineering design solution, social factors, science content knowledge, and mathematical skills all come into play (Roehrig et al. 2008).

The connections to science, mathematics, social studies and ELA are rich in an integrated instructional environment. A large part of engineering design involves recalculating, redesigning, recording and communicating the work, which brings in math and literacy skills. When the engineering challenge stems from a societal need, all content areas can be integrated into the problem-solving process. While the benefits of integrated instruction such as solidifying science concepts through engineering design and incorporating technology to make mathematical learning fun, McClure et al. (2017) warn against attempting to teach everything in an integrated fashion without intentionality to ensure that integration maximizes student learning. An additional caution is that while teachers may exhibit positive attitudes about the value of content integration, the feasibility of implementing an integrated curriculum can be challenging (Berlin & White, 2012; Carrier, Tugurian, & Thomson, 2013).

**Implications**

The science reform agenda clearly calls for a transformation in science education in the United States. The change is necessary to build a more capable and interested group of young adults pursuing STEM fields. The NGSS are designed to pique student interest in science by providing experiences similar to the actual work of scientists and engineers, rather than merely memorizing facts or reading about science in a textbook. The NGSS has provided a set of standards, developed around recommendations outlined in the Framework that is grounded in a
hands-on, inquiry-based approach to science that promotes conceptual understanding of science phenomena and incorporates engineering practices. States have the opportunity to develop curriculum that fits their district. However, given the emphasis on high stakes testing subjects such as ELA and mathematics, there is limited time in the instructional day for science.

In heeding the call of the reform agenda, districts may be able to maximize instructional time by implementing an integrated instructional model. The shift is not an easy one, particularly given the minimal amount of time and resources currently dedicated to science at the elementary level. The integration of engineering principles with science instruction and the integration of science with other core areas can benefit elementary educators. The barriers that currently prevent curricular integration must be removed and educators must be provided with the training, resources and equipment necessary to effectively teach science and engineering practices at the elementary level.

**Improving Resources and Training**

There are several factors that contribute to the current state of science instruction in the United States. Accountability to high stakes testing in Mathematics and English Language Arts, which are often directly tied to teacher performance, have a role in the limited amount of time allocated to science instruction. Elementary teachers are unlikely to have trained extensively in scientific and engineering content or methodology (Capobianco, 2010). Additionally, the lack of quality resources contributes to the inconsistent teaching of science in a manner that engages students in science at the elementary level. Elementary teachers face constraints that their secondary counterparts do not. Many were likely not trained in science content and pedagogical practices and therefore, need support and ongoing training as well as adequate resources made readily available, such as a kit-based program.
**Elementary Teachers are not Content Area Experts**

Increasing time and attention dedicated to science requires a shift in the current thinking and instructional methods implemented in American schools. There are several barriers that prevent the successful implementation of the reform agenda objectives including; elementary educators’ level of scientific content knowledge, the level of preparation and training elementary educators receive, as well as a lack of adequate resources made available to teachers. Those with backgrounds in technology tend to teach at the secondary level and few elementary teachers have background training in science or engineering (NRC, 2009). Since so few elementary teachers have experience in science and engineering fields, it is logical that science and engineering may cause feelings of uncertainty (Capobianco, 2010) and ultimately be subjects that elementary teachers are simply not comfortable teaching.

Instructional leaders must make it a priority to provide the time, training, and resources to develop educator capacity. Curricular integration is an effective method to increase instructional time by positioning engineering in the context of one or more content areas that the elementary educator is comfortable and familiar with. While integration allows for precious instructional time to be devoted to multiple content areas, rather than trying to teach math, science, social studies and ELA in isolation, however, increasing instructional time is only a part of the solution. Elementary teachers face the teacher accountability aspects of high stakes standardized testing in mathematics and ELA. Berlin and White (2012) report that “standardized testing and accountability issues make content integration more challenging”. If state accountability measures only focus on the math and ELA results, which are tied to educator performance scores in many states, naturally the time allotted to those content areas is greater. Demonstrating the
value that science add to the classroom through professional development and training opportunities is necessary if we expect to see a shift in instruction.

Instructional leaders can provide training experiences to help remove barriers for educators, however, if the educators do not find value in the training it is a useless endeavor. Appleton (2002) sought to identify teachers’ perceptions of science activities that “work” for them. In the study, twenty Australian teachers were interviewed, and sixteen were observed, to determine what they feel constitute an activity that works; either for the students, the teachers or both. The common themes that emerged indicated that activities that work are; a) hands-on; b) interesting and motivating for the children; c) manageable in the classroom; d) have a clear outcome or result; e) draw on equipment that is readily available; and f) lend themselves to integration. The author notes that there were repeated comments from the teachers about their initial lack of confidence and how their confidence improved using activities that worked in the classroom. It is the educational leaders’ responsibility to ensure that teachers are equipped with proven materials and resources necessary to teach science with confidence since elementary teachers are not content area experts.

**Educator Preparation**

High quality, thoughtful professional development proven to have a positive impact on instruction is necessary to improve elementary science instruction. Most elementary education undergraduate programs place emphasis on ELA and mathematics. Aspiring educators often do not have many opportunities to practice their science instruction, and even more rare their engineering instruction. Additionally, educators need not only preparation in the scientific content but also in pedagogy, specifically the nature of science and scientific inquiry (Bartos & Lederman, 2014). In an attempt to provide more experience with the practice of science
education, Wallace and Brooks (2015) worked with preservice teachers in an informal classroom setting, a summer camp, for their elementary science methods course teaching experience. The authors state that the lack of time dedicated to science in the traditional classroom has led them to explore other options for providing teaching experience outside of the traditional classroom. The educators were placed in groups of six. While one was teaching a lesson, the others had the opportunity to work with small groups of students, work one on one with students, and help manage the classroom environment. The unique experience of being able to work closely with small groups of students and listen to their ideas provided the preservice teachers with insight into students’ scientific thinking. Overall, the participants were surprised at the level of knowledge and reasoning the children possessed. In a traditional teaching experience, it may take months for a teacher to be able to obtain the depth of knowledge and reasoning students have, thus these results indicate that there may be benefit in providing educators with professional development opportunities to listen closely to students as they engage in science experiences while someone else delivers the instruction.

The benefits of engineering integration can be great; however, the time and ease of planning integrated lessons or units can be difficult for elementary educators. Berlin and White (2012) sought to determine the attitudes and perceptions on STEM integration among preservice educators. They studied seven years of cohorts in a Math, Science and Technology Program at a University in Maryland in their study. The preservice teachers’ attitudes and perceptions were measured using a twenty-item scale. The results demonstrate positive attitudes from participants about the value of integration, yet concern over the challenges that accompany it. The results of the study indicate that teachers need support in reducing the preparation and planning required to teach effective integrated STEM units. Instructional leaders must provide staff with effective and
efficient resources, time to work together to plan integrated lessons, and targeted professional development on content integration.

A potential area for targeted professional development for elementary educators to provide more comfort in teaching engineering could be to educate them on the engineering experienced in their daily lives that can be brought into the classroom. The Institute for P-12 Engineering Research and Learning (INSPIRE) developed an engineering institute for educators to help develop an understanding of engineering around them daily. In 2006 and 2007, 40 teachers participated in a week-long institute. The participants were asked to document their experiences with the engineering-based activities in journals and via photographs. Prior to the institute the participants were instructed to take ten photographs of engineering that they saw in the world. During the institute participants also documented evidence of engineering after learning from the institute, in an attempt to gauge their level of understanding of engineering in the world around them. The photographs and journal entries indicated that the participants increased their ability to recognize and better understand engineering (Duncan, Diefes-Dux, & Gentry, 2011). While not all of the areas measured indicated significant gains, there is an implication that photo journaling may provide a positive experience to teach educators and students about engineering in the real-world.

In an attempt to alleviate some of the difficulties experienced by educators in regard to STEM integration, Nadelson et al. (2013) utilized the sySTEMic Solution, which was developed by college professionals, to increase teachers’ capacity in teaching inquiry-based STEM. Nearly 70 educators participated in a summer institute and a year-long professional development series. The participants engaged in hands-on activities, lecture, and small group discussion in an attempt to increase their confidence and efficacy in teaching STEM as well as increase their content
knowledge in STEM curriculum and in the work of career STEM professionals. The participants increased their knowledge and confidence in teaching STEM (Nadelson et al., 2013). Professional development opportunities that provide educators with hands-on experiences similar to those the students will experience are valuable in increasing confidence and capacity in teaching science and engineering principles.

Teaching hands-on, inquiry-based science can be anxiety inducing for elementary teachers. Anxiety combined with little incentive to teach science at the elementary level due to the focus on high-stakes tested content areas, may make science instruction “expendable” (Dickerson, Clark, Dawkins, & Horne, 2006). Another contributor to the anxiety of teaching science may be the loss of control felt in hands-on, inquiry-based instruction such as is called for in the NGSS. Student motivation and engagement increase in classrooms where teachers provide autonomy supportive environments (Niemiec & Ryan, 2009; Reeve, Jang, Carrell, Jeon, & Barch, 2004; Pelletier, Séguin-Lévesque, & Legault, 2002). It may be more common for teachers to exhibit controlling motivational styles (Reeve et al., 2004), however educators can benefit from professional preparation on adopting a more autonomy supportive motivational style. Niemiec and Ryan (2009) state that minimizing evaluative pressure and coercion while increasing “students’ perceptions of having a voice and choice” in academic activities are ways of promoting autonomy support. Reeve (2009) provides five instructional acts to help teachers become more autonomy supporting, including: a) nurturing inner motivational resources; b) providing explanatory rationales; c) relying on non-controlling and informational language; d) displaying patience to allow for self-paced learning; and e) accepting when students express a negative affect. Given the nature of hands-on science instruction, supporting educators in autonomy supportive motivational practices may benefit both teachers and students.
Kit-Based Science Programs

Kit-based science programming is not a new concept. Kit-based science programs have been in circulation since the 1960’s (Jones, Robertson, Gardner, Dotger & Blanchard, 2012) and have shown to have a positive impact on student achievement (Young & Lee, 2005; Dickerson et al., 2006), student attitudes toward science (Kelly & Staver, 2005; Houston, Fraser & Ledbetter, 2008), and provides teachers with tools to enhance science learning (Robardey, Allard & Brown, 1994; Slavin, Lake, Hanley & Thurston, 2014). Some widely used kits include FOSS, which were first developed in the late 1980’s and pilot tested in San Francisco. The Science and Technology for Children (STC) kits through the Carolina Biological Supply Company have been in use since the late 1990’s. In New York State, various regional BOCES services also develop kits for districts to loan. When determining science resources appropriate for a school district, instructional leaders must consider student learning objectives, teacher comfort levels, and budgeting when selecting a resource. Kit-based programs can be expensive yet they provide most of the materials teachers need to deliver high-quality instruction.

The kits developed in the 1990’s were widely implemented, however, once federal funding sources dried up they were difficult to maintain in districts, both in resource management and teacher training (Young & Lee, 2005). FOSS and STC are two popular kits that have survived the lull in kit-based program use. There are no studies that examine the effectiveness of the newly aligned NGSS kits, however there is research to support the use of kit-based programming in general. Student achievement and student interest are two important components to consider when selecting a science program. Young and Lee (2005) found that a group of fifth grade teachers using high-quality materials in a kit-based program resulted in better student achievement compared to teachers using traditional materials despite spending
more time on science instruction. Houston et al. (2008) assessed classroom environment in a study where one school used textbooks for science, the other used science kits, and the third used textbooks and kits. Students in the kits-only group experienced higher levels of classroom environment satisfaction and cohesion.

While kit-based science programs are effective in many ways, sustained, high-quality professional development is a key aspect to an effective kit-based program implementation. Kelly and Staver (2005) conducted an extensive case study on one district’s implementation of a kit-based program, the Discovery Works series. Some of the teachers’ primary concerns are consistent with other kit-based programs; time needed to prepare lessons and store a vast amount of materials, an overwhelming feeling of dealing with a new series and confidence in teaching science, and vocabulary and assessments. Districts must ensure that a plan to alleviate the concerns about storage and replacing consumable materials is in place, and most importantly that ongoing professional development in utilizing the new kits is provided. If these assurances are not in place, the implementation of a new kit-based series can easily stall.

Since the development of the NGSS companies have updated their kits to fit the model of the new standards. School districts are evaluating their current materials and resources to determine alignment to the new standards. In many districts is clear that current resources and materials are insufficient in providing students high-quality science instruction aligned to the NGSS. Improving science instruction at the elementary level will require districts to support teachers’ content knowledge, limited amount of instructional time, and provide appropriate resources (Slavin et al., 2014). A best-evidence synthesis on elementary science programs by Slavin et al. (2014) revealed mixed results in regard to kit-based implementation but does provide important considerations. One finding indicates that there was more improvement in
achievement in studies where pedagogy was the focus rather than the implementation of a kit. Another is that teachers may focus so much on properly implementing the materials in a new kit that they do not focus on developing student understanding of concepts. However, there also appears to be more accurate scientific content taught when using a kit-based program.

The research on kit-based programs, although evaluated prior to the adoption of the NGSS, show mixed results in regard to student achievement but do appear to demonstrate an increase in student interest. It is clear that the implementation of a kit-based program must include high quality, ongoing professional development in both implementation of the actual resources as well as pedagogical approaches to science instruction. The more professional development experiences and scientific and pedagogical content knowledge teachers have, the more likely a kit-based implementation will be successful (Jones et al., 2012).

Implications

McClure et al. (2017) conducted an extensive survey involving prominent researchers, stakeholders, and teachers to better understand challenges and opportunities in early STEM education. Their findings support the arguments outlined in this section that elementary teachers, while not science and engineering content experts, are willing and capable of teaching early STEM education but need additional knowledge and support in the form of training and resources. Simply increasing the amount of instructional time on science without a change in instructional practice, such as a focus on a more student-centered instructional approach, may not increase teachers’ self-efficacy in teaching science (Sandholtz & Ringstaff, 2014). Additionally, kit-based program implementation may be helpful in increasing the amount of time and attention dedicated to science but must be thoughtfully implemented in conjunction with educator training.

Engaging Elementary Students in Science
Educators and parents often witness firsthand the natural curiosity for exploration of the world that children possess. Science in the elementary setting provides an opportunity to capitalize on that innate curiosity, to tap into children’s exploratory nature. Eshach and Fried (2005) advocate for exposing young children to science to develop positive attitudes towards science and lay the foundation for deeper understanding of science, scientific thinking, and scientific concepts. This section will examine the benefits of engaging elementary students in science and potential consequences of not exposing all students to science and engineering early on in their educational careers. Some benefits include increased competence in their abilities and the development of a personal identity with science. Some consequences include perpetuating the gender gap and stereotypes.

**Benefits of Early Exposure to Science**

Students may have already developed misconceptions regarding the correlation of intelligence and ability (Redmond et al., 2011) and attitude (Turner & Ireson, 2010) in science by the time they are in middle school. In other words, students may falsely think that science is only for smart people. Early and repeated exposure to high-quality science and engineering instruction has been linked to a potential increase in sense of competence, interest, student confidence and attitudes regarding science and engineering (Capobianco et al., 2015; Mantzicopoulos, Patrick, & Samarapungavan, 2008). Considering that students may develop a sense of self regarding science intelligence and aptitude as well as an attitude toward science by the time they are in middle school, it is necessary to provide deep and effective science and engineering curriculum at a young age so as to prevent those misconceptions from forming. Introducing all students to science and engineering concepts in elementary school is important because student interest in science begins to decline around the age of nine or ten (Roberts, 2014). Knight and Cunningham (2004) note
that female students have demonstrated negative attitudes about their scientific ability as early as second grade.

Active engagement in science and scientific discourse, rather than passive attainment of information, contributes to the development of attributes helpful in better understanding the role of scientists. Capobianco, French, and Diefes-Dux (2012) report, “students’ communication and participation in science enable them to learn the structure of the discipline and, furthermore, contribute to the formation of their science identities” (p. 701). Talk is a key component in developing identity (Howard, 2000). The more students engage in science and engineering, the more they talk about it, therefore using academic terminology and science and engineering discourse. Yu, Luo, Sun and Strobel (2012) find that introducing engineering practices early on can foster an interest in engineering and possibly encourage students to consider engineering as a career. The absence of science and engineering in the primary and elementary grades results in fewer opportunities to participate in scientific discourse, and fewer experiences in which students are able to learn about the discipline and develop interest as well as competence in their scientific ability.

One cannot be expected to know their level of interest or competence in something if they have not had exposure to it. The same is true for scientific and engineering practices. Knight and Cunningham (2004) developed the “Draw an Engineer Test” to assess student understanding of what an engineer is and what he or she does. The survey was administered to 384 students between grades three and twelve. Results indicated that 58% of the students thought engineers built or fixed things, although 12% of older students tended to have a better understanding of the design aspect of engineering. Upon closer examination, building and fixing was often associated with repair type activities such as repairing a car, a computer, or plumbing. When asked what
materials students associate with engineers, 64% replied tools, cars, a hard hat or a train. Knight and Cunningham assert that middle school is a crucial time for planning future courses and potential career options. “The perception that engineers are car mechanics could discourage female students from considering engineering as a possible career” (p. 4). Early exposure to science and engineering, including career exploration could prevent some of the deep seeded misconceptions from forming.

Capobianco et al. (2015) used the Engineering Identity Scale (EIDS) in a study of students in grades one through five to determine the level of their engineering identity. The scale was administered to 274 students prior to and after their participation in a series of activities in an engineering based curriculum. The same scale was administered to a comparison group consisting of 276 students in grades one through five who participated in a traditional standards-based curriculum. Both female students and students in the younger grades showed substantial increases on the EIDS scale. Girls in all age groups that participated in the engineering-based curriculum demonstrated a strong self-concept in regard to problem solving. Younger students were more likely to have a better understanding of the work of an engineer after participating in the engineering-based curriculum. In general, the engineering-based group demonstrated greater improvement on the two subscales, academic performance and engineering career, than did their peers in the comparison group. The results indicate that more students in the lower grades developed positive aspirations for an engineering career than did the students in the higher age group. Addressing misconceptions of engineering as a profession by introducing students to engineering based activities at an early age can help students develop better vocational identity awareness.
**Competence.** According to Self Determination Theory (Deci & Ryan, 1985), competence is one of the factors integral in attaining optimal motivation. Carlone and Johnson (2007) developed a three-dimensional model of science identity, which includes performance, recognition and competence, with the three dimensions overlapping. The model is designed as a ranking system to determine whether a person has a strong science identity; ranking oneself highly and being ranked highly by others in the three areas indicates a strong science identity. One with a strong performance identity would be considered proficient in using scientific discourse and scientific tools. Recognition refers to one recognizing oneself and being recognized by others as a “science person”. Competence refers to the actual scientific knowledge acquisition and understanding a person has, which may not be as outwardly observable as performance indicators. The underlying assumption of the model is that one’s racial, ethnic, and gender identities have an impact on one’s science identity formation. Carlone and Johnson (2007) contend that, “a science identity is accessible when, as a result of an individual’s competence and performance, she is recognized by meaningful others, people whose acceptance of her matters to her, as a science person” (p. 1192).

Brown (2006) explains that learning the cultural practices of the science classroom can take time for students. Students can benefit from obtaining acuity in scientific discourse by the way of opportunities, both socially and educationally. Unfortunately, a scientific discourse can also cost students, particularly those in conflict with their own identity and the identity as a student of science. In order for students to be acculturated in science, or identify with self as a student of science, Brown identifies three influencing aspects of science culture; science epistemology, the practices of scientific research, and science discourse. Students tend to struggle the most in the discursive aspects of science; that is, the public use of scientific
discourse conflicts with students’ own identity and despite acquiring an ability to apply a fluent scientific discourse (Brown, 2004), they may fail to transcend that identity beyond the science classroom (Brown, 2006). In terms related to SDT, the competence that one acquires may not be enough to overcome the stigma of the loss of relatedness when compromising one’s identity to those outside of the science, “in group”.

In an executive summary evaluation of the Engineering is Elementary program Cunningham and Lachapelle (2011) discovered that girls’ and boys’ responses to many survey questions were different, particularly regarding engineering careers. Boys express more interest in areas such as “inventing, figuring things out, cars, and structures; girls showed more interest in the jobs to do with helping society and people” (p. 9). Female interest in engineering was shown to increase significantly after exposure to a high quality, engineering program. This shows that while an exercise may be the same in an elementary classroom, the experience may differ between male and female students based on their preconceptions, past experiences, and sense of competence. Brickhouse (2001) advocates that in order to understand learning in science one must look beyond the science content to better understand what aspects of science drive students and their potential aspirations.

**Identity.** Participation in engineering activities integrated into the elementary classroom can have a lasting impact on a students’ identity development. In a study that took place in the United Kingdom, Roberts (2014) pre-tested a group of students with a module titled, “Could you be a scientist?” and then again after the introduction of several science and engineering related lessons. In the pre-test, 78% of the seven to eleven year old students indicated that they were, “unsure” of what engineering was. In the post- test 48% of students were still “unsure” about what engineering was, even though only one of the lessons focused explicitly on engineering, the
rest were loosely embedded. The most significant change in response to questions from the pre to post-test was to the question, “I think I could have a job as a scientist”, indicating an increase in how students feel about science.

Capobianco et al. (2012) adds to the notion that early exposure has an impact on identity and posits that student participation in science not only enables them to learn about the discipline, but contributes to the formation of their science identity as a young learner. The positive and negative experiences that students have with content in elementary school plays a role in their formation of identity. Exposure to science and engineering concepts in a positive, engaging, fun and collaborative manner in elementary school may contribute to more students with a higher sense of self as a student of science. Developing an ability to utilize scientific discourse and fostering scientific literacy may make students feel like members of the scientific community (Brown, Reveles, & Kelly, 2005), thus fostering their identity of self as a student of science.

Brickhouse and Potter (2001) document how marginalization impacts membership in a school science community as well as the difficulties faced by students who desire to be part of a community that conflicts with their identity. Identity develops as one participates in their environment and the manner in which one takes into account the reactions of others in regard to the viability of that identity. Schools can marginalize students by so narrowly defining the parameters of a scientific identity that it is unachievable or undesirable by certain populations of students. In their case study, Brickhouse and Potter (2001) discovered that the student who was able to find the greatest success in a scientific community, while not the most academically talented, was deemed to be in an environment in which her identity was desirable, as opposed to
restricted, in that community. This is directly connected to the notion of relatedness in SDT, as one sees themselves as either being part of the in group, or not being part of the group.

It is important to improve student confidence and attitudes regarding science beginning in early elementary school so that it transcends into the important decision-making stages of an educational career. If students are not provided with opportunities to develop their competence with science and engineering they may feel inferior to peers who display such proficiencies, thus thinking of themselves as inferior STEM students. Introducing all students to science and engineering concepts in elementary school may provide them with the competence, confidence and aptitude to engage in STEM content throughout middle school, high school, and possibly into a career.

The Gender Gap

A gender gap exists in the fields of science and engineering (Archer et al., 2012; Smyth & Nosek, 2015). Despite the gap narrowing in the biological sciences, physical science and engineering continue to suffer from a significant gender gap (Smyth & Nosek, 2015; Jones, Howe, & Rua, 2000; Nugent et al., 2010). There are fewer females in the fields of science and engineering compared to males (Blickenstaff, 2005) and fewer females obtain credits in STEM subjects in high school than do their male counterparts (NCES, 2015). Additionally, more women enter into biological sciences than physical sciences or engineering (Andersson, Husseniuss, & Gustafson, 2009; Brickhouse, 2001; Smyth & Nosek, 2015).

Science, Technology, and Engineering professions could suffer a shortage of employees because fewer students are entering into those fields as majors in college (Marulcu, 2014; Nugent et al., 2010; Olson & Riordan, 2012). These findings are consistent with Cunningham, Hoyer, and Sparks (2015) in that despite more female high school graduates taking advanced
math and science courses in 2009, male students reported liking math and science more and performed higher on math and science on the NAEP. While 5.6% of high school graduates earned engineering credit, only 1.1% of female students did. The largest discrepancy in earning STEM credits was in Advanced Biology, with over ten percent more female students earning credits than male students.

There are many possible reasons that female students have a negative attitude toward the physical sciences, such as strong negative feelings about dissection, less aggression in attaining classroom materials compared to male counterparts, and a lack of positive experiences both in and out of school (Blickenstaff, 2005). Female students may respond more positively to biological sciences due to a stronger interest in the humanitarian aspects of science, including helping others (Jones, et al., 2000). Additional factors, such as environment, can contribute to gender related positive or negative attitudes about engaging in stereotypical STEM perceptions, these are labeled as stereotype threats (Shapiro & Williams, 2012). A stereotype threat is “a concern or anxiety that one’s performance or actions can be seen through the lens of a negative stereotype” (p. 175).

The pre-school attitudes and perceptions that children develop about science are directly related to the role models children have and the types of scientific and engineering related experiences they have prior to entering school. Throughout childhood and adolescence, girls and boys do not have the same experiences with science. Jones et al. (2000) determined over twenty years ago that science experiences outside of school are different for girls and boys. Males reported many more extracurricular experiences with science outside of school than did girls. Everyday experiences at a shopping center, with the pink isles of girl toys and the blue isles of boy toys indicate that children’s earliest experiences are defined by gender. Toys and play
constitute a young child’s experiences with learning how the world around them works as well as how they fit into it. Fostering an early science interest in female students may result in a better self-concept about science later in life (Leibham, Alexander, & Johnson, 2013).

There are many factors, including personal, social, and environmental influences that contribute to a persons’ decision to pursue a particular career. Previously established is the notion that there is a lack of female engagement in science and engineering fields. Blickenstaff (2005) conducted an extensive review of literature to determine factors contributing to female students’ lack of engagement with STEM careers. Of the nine factors identified, three are particularly significant to the study of elementary science education: a) girls’ poor attitude toward science and lack of positive experiences with science in childhood; b) cultural pressure on girls/women to conform to traditional gender roles and; c) the “chilly climate” that exists for girls in the science classroom. American schools have a responsibility for preparing the next generation of children to inherit the demands of the workforce. Swarat, Ortony, & Revelle (2012) write that it is important to provide science and engineering instruction in the elementary grades in order to develop an interest in science and engineering so that those students may contribute to the next generation of American scientists.

**Stereotypes**

Females may not be attracted to science and engineering fields due to their perceptions of science and engineering. Students in Roberts (2014) study described scientists as boring men that work in laboratories. Carlone (2004) suggests that in order to attract more female students to science in schools, we need to modify the activities and meaning of science to be more inclusive. The results of Carlone’s study revealed a theme present in the work of Brickhouse (2001) about the perception of a “good girl” student. The perception of what a “good girl” student is conflicts
with the perception of a student that is good at science. Female students may be concerned with maintaining a good girl student identity and view engaging fully in science as a conflict to that identity (Carlone and Johnson, 2007). Female students may not speak out in a science class or engage in a scientific community because it conflicts with a “good girl” student identity (Brickhouse, 2001).

Students may view science as narrowly defined subject with finite answers. Female students prefer fields with a broader spectrum that permits more choice and exploration of opportunity, which could offer explanation as to why girls prefer biological sciences and disciplines in which one can care for others or animals (Brickhouse, 2001; Carlone & Johnson, 2007; Blickenstaff, 2005). Carlone (2004) asserts that school science is socially constructed in ways that marginalize particular groups, including women to the fields of physics. The program that she evaluated and deemed to have positive results was a high school physics unit which provided access to content otherwise thought of as too scientific for some students or reserved for students good at physics. The perception of science being only for the elite and untouchable for others (Carlone, 2003) must be addressed in order to provide access to science for all students.

The science and engineering classroom environment can be uninviting to female students. Blickenstaff (2005) attributes some of the female student lack of interest in science to factors that occur in the science classroom that devalue female student efforts. Some of the factors mentioned include poor behavior from male counterparts in science class, a sense that the teacher underestimates female student ability, and male harassment of female students in post-secondary science fields. Smyth and Nosek (2015) found that male scientists have strong stereotype beliefs that science is a male profession. This belief may contribute to female students feeling inferior to male students throughout science educational experiences and may serve to perpetuate the
marginalization of female students from science. Moss-Racusin, Dovidio, Brescoll, Grahan, and Handelsman (2012) examined undergraduate faculty bias in regard to female students in an attempt to determine if faculty bias plays a role in fewer females entering into STEM fields. The study confirms that faculty, both male and female, exhibit gender bias against female students in regard to their perceived competence.

Female students, even gifted female students, have lower perceptions of self as a student of science than their male counterparts (Miller et al., 2007). While the interest level in science declines for both male and female students around middle school, the decline is sharper for female students. Perhaps the explanation for the decline in interest is the science classroom environment itself (Miller et al., 2007). Addressing the long term impact of negative stereotypes may require a shift in classroom instruction. Hands-on science activities which are physically and intellectually engaging are of high interest to students; these activities also appear to promote autonomy and competence through the inquiry processes involved in the exploration (Swarat et al., 2012).

**Implications**

Introducing science and engineering early in a student’s formal school career may serve to improve student competence and identity with science, particularly in female students, as well as help remedy misconceptions of science and engineering stereotypes. Early and repeated exposure to science and engineering provide more opportunities to engage in scientific discourse, and therefore, potentially develop a deeper sense of competence for self as a student of science. Perhaps if elementary students received high-quality science instruction that promoted autonomy, competence and relatedness, female students would develop a stronger sense of self
as a student of science, which could eventually lead to more female interest in science and engineering fields.

**Conclusion**

The widespread adoption of the Next Generation Science Standards, coupled with the national push for STEM education provides an opportunity to rewrite the current narrative in science education. Introducing all students to high quality science and engineering instruction, beginning in Kindergarten, is a primary objective of the NGSS. Removing the factors that contribute to the lack of interest in science and engineering is necessary if the new standards are to be implemented successfully and if the United States hopes to increase the number of students entering into science and engineering fields. The recent science reform agenda calls for a shift in science education in American schools. The design and reiterative processes in engineering provide educators with an inquiry-based instructional model. Integrating engineering with science and science with other core content areas may provide elementary educators with more time to teach science. Educators must promote critical thinking and problem solving skills in a real world context and provide students with opportunities to behave like actual scientists and engineers. Engineering problems set in real-world scenarios allow for learning experiences that occur similarly to learning in the real-world and involve curricular integration of core areas, not instruction in isolation.

Aligning elementary science instruction to embrace the spirit of the NGSS will provide students with challenging, hands-on science and engineering experiences that offer opportunity to engage in the work of real science. The shift in instruction will require intensive and ongoing professional development and training in both science content and pedagogy. Elementary educators are not content experts and do not have the access to materials and resources to teacher
science that their secondary counterparts do. Providing high-quality resources are an invaluable tool for teachers, but educational leaders cannot expect teachers to implement a kit-based program without training and support.

The importance of early and frequent exposure to science and engineering can challenge student misconceptions about science and engineering and may improve student perceptions about their own science ability. Science and engineering instruction has shown to play a role in student identity development and improvement in student understanding of the role that scientists and engineers play in helping others. The largest gender gaps exist in the physical sciences and engineering fields; providing female students with opportunities to see how science and engineering can help others may spark interest in disciplines other than biological sciences. A gender gap exists in the fields of science and engineering and has been documented at various levels of public education, particularly middle school through post-secondary school. There are several factors that play a role in the gender gap. Some of the factors that can be addressed at the elementary level include environmental factors, addressing stereotypes, and improving the classroom environment so that it is more friendly to females in science and engineering. Educators cannot control the exposure to and experiences with science and engineering prior to a student entering school, however, they can provide all students with high-quality science and engineering instruction beginning in Kindergarten.
Chapter Three: Research Design

The lack of adequate resources is a contributing factor in the inability of modern educational institutions to engage elementary students in science. A kit-based science program is an example of a resource intended to assist educators in providing high-quality, hands-on science instruction that engages students in science. There are currently no studies that examine the impact of the NGSS version of the FOSS kits on teachers’ competency in engaging students in science. Therefore, this qualitative study was intended to better understanding teachers’ lived experiences with teaching FOSS kits. The following research question served as the focus for the study:

How do teachers describe their understanding of the impact of FOSS on their ability to engage students in science?

The purpose of answering this question was to better understand teachers’ perceptions with the experience of teaching FOSS and the impact FOSS has on their ability to engage students in science. Knowledge generated from the study will serve to inform instructional decision making in the district to foster teacher competency and student engagement. It is important to understand teachers’ feelings of competency in teaching science as it can be a factor in their motivation to allocate time to science instruction.

Qualitative Research Approach

The term research broadly refers to structured inquiry “by which we know more about something than we did before engaging in the process” (Merriam, 1991, p. 43). Creswell (2002) describes qualitative research design as a process that seeks to explore a phenomena through participants’ experiences. The qualitative research methodology is used when the variables involved in the study’s research question are unknown. Miles, Huberman, and Saldana (2014)
describe qualitative research as collecting data in the form of words, which are analyzed and processed by the researcher. A qualitative methodology is appropriate for this study as the researcher seeks to better understand the participants’ lived experiences.

There are various research paradigms that can be utilized in a qualitative study depending on the question the researcher wants to answer. Ponterotto (2005) defines a paradigm as a, “set of interrelated assumptions about the social world which provides a philosophical and conceptual framework for the organized study of the world” (p. 127). The constructivist-interpretivist paradigm is best suited for this study as it assumes that a researcher is closely connected to the process of data collection and to the participants being researched. The constructivist-interpretivist researcher does not believe that reality is an object, but rather a construction of the human mind. The world, including its people, is ever changing, it is not a static phenomenon nor can it be measured in that way. Given this theory, the research must measure beliefs and context rather than isolated facts (Merriam, 1991).

Butin (2010) explains that the constructivist-interpretivist researcher believes that the world is ever-changing and shaped by human interactions and involvement. The researcher believes that she is part of examining the truth as she lives it, not setting out to find an absolute truth. The truth, in fact, does not exist as one answer to be found, the truth is dependent on the perspective in which it is being examined. A constructivist-interpretivist researcher may not use large scale surveys but rather study a small number of people over a long period of time via in depth interviews, frequent conversations and close interpersonal contact. Consensus among the results are not critical as the researcher is not seeking out a single truth but reporting on the construct of the phenomenon. Since the researcher works closely with the participants in order to make meaning of their experience, an interpersonal relationship is established between the
researcher and the participants. This is different from other forms of research, such as postpositivism, where the researcher maintains distance from the participants. In constructivist-interpretivist research, the research itself is value-dependent and subjective; it is about making meaning and understanding based on the context observed and evaluated (Ponterotto 2005).

**Interpretative Phenomenological Analysis**

Phenomenology is a type of qualitative research and will be used as the basis for this study. Phenomenology stems from a variety of influences and perspectives, it is currently utilized in multiple research approaches (Dowling, 2007; Larkin, Eatough, & Osborn, 2011; Shinebourne, 2011). Two major categories of phenomenological research are descriptive and interpretive, founded by Edmund Husserl and Martin Heidegger, respectively (Reiners, 2012). Phenomenology originated in Germany early in the Twentieth Century as a means of understanding an experience by examining it to uncover its meaning (Smith, Flowers, & Larkin, 2009).

One strategy for better understanding the common experience of participants is through phenomenological reduction, or getting to the “essence” of the matter (Dowling, 2007). Husserl’s approach involved describing the experiences of others while setting aside preconceived notions, whereas Heidegger brought in the idea of interpretation, or hermeneutics (Reiners, 2012). A key difference in the two approaches is that one seeks to describe the experience (descriptive) versus making meaning of the experience (interpretive). Reiners (2012) explains that interpretive phenomenology is used when a researcher does not bracket out their bias and knowledge of the research question as hermeneutics assumes previous understanding of the problem. This study will employ interpretive phenomenology, specifically Interpretive Phenomenological Analysis (IPA).
An Interpretative Phenomenological Analysis is often conducted on small sample sizes due to the length of time and level of detailed analysis involved (Smith et al., 2009). The participants in an IPA study have all experienced a common phenomenon and the researcher seeks to make sense of their collective experiences. IPA is an enticing choice for a study methodology due to the accessibility, flexibility, and applicability (Larkin, Watts, & Clifton, 2006) to a broad range of topics. An Interpretative Phenomenological Analysis is an appropriate choice for a study aimed at making meaning of how teachers describe their understanding of the impact of FOSS on their ability to engage students in science. The IPA methodology will allow the researcher to derive at the essence of the experiences of multiple participants and to make meaning of the phenomenon by situating her expertise of the subject matter into the interpretive process.

There has been much scholarly debate over the role of the researcher in an IPA study. The general thought is that by stepping outside of an experience and examining it thoroughly, the researcher can identify multiple perspectives of that experience. The researcher’s role in IPA has evolved from identifying the essence of participant’s experience to actually interpreting what the experience means (Smith et al., 2009). Naturally, making meaning of a person’s experience is an interpretive process; making meaning of a group of people’s common experience requires multiple layers of interpretation. According to Smith (2004), an IPA study has three distinguishing characteristics; it is idiographic, inductive, and interrogative. An IPA study is also hermeneutic and idiographic because the researcher makes claims about the experience of the individual being studied (Shaw, 2010).

In an IPA study, the researcher is engaged in a double hermeneutic process; making meaning of the participants meaning-making of an experience. Therefore, the researcher is only
privy to the information about the experience to the extent that the participant shares it, thus the interrogative nature of the methodology. The process is idiographic in that it seeks to understand an experience as the participant experienced it and also understand how that person made sense of that experience (Smith et al., 2009). It necessary for the researcher to thoroughly examine each case as its own and deeply understand it prior to leaping to more general or broad claims about the collective experiences of the group. The data analysis process is iterative, not linear (Crist & Tanner, 2003), and tends to move from the individual to the shared essence. The iterative process results in moving from descriptive coding of the data to interpretive meaning making. The process of continually moving from parts of the data to the whole of the data is then brought together into a cohesive narrative. The presentation of the findings should allow the reader to make sense of the researcher’s analysis of the participant’s experience (Smith et al., 2009; Reiners, 2012).

Participants

The participant pool consisted of a homogeneous group of teachers who would otherwise not collectively come together to make meaning of their common experience. The nine participants were Kindergarten through fifth grade teachers who have taught the FOSS science kit pilot. All participants work for the Fairport Central School District. Six participants were female and three were male. The location of the interviews took place at a location selected by the participant, none of which were in the researcher’s office. Voluntary purposeful sampling was utilized as the teachers’ were required to have participated in the FOSS pilot to be considered a potential participant. IPA studies require a small number of participants in order to obtain extensive, interview-based data. Yet, the participant pool must be large enough to obtain
trend data from which to interpret the phenomenon being studied. Therefore, the pool of nine participants was ideal for this study.

In the constructivist-interpretivist approach, interaction through a dialogue between the researcher and participants is necessary and allows for deep meaning making (Ponterotto, 2005). In order to better understand how the FOSS kits impacted teachers’ ability to engage students in science and eventually determine if the resource is a feasible one for the district, the researcher needed to make meaning of the “lived experiences” of the teachers (Ponterotto, 2005). The interviews of nine participants yielded rich interview data from which to draw conclusions about the impact FOSS had on their ability to engage students in science.

Participants were sought through a participant recruitment letter. The letter was sent via email to all teachers in grades Kindergarten through fifth grade that piloted FOSS in year one or year two of the pilot. The purpose of targeting year one and two participants initially is that they have had more experience with FOSS and would likely provide a richer data set that those using FOSS for the first time this year. The researcher was prepared to send a second recruitment letter to teachers that joined the pilot for the first time this year should the initial recruitment phase fail to acquire at least eight participants. However, the initial recruitment yielded nine participants and the second letter was not necessary. The participants and their corresponding grade band as well as the number of years in the pilot are listed in Table 1.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Grade Band</th>
<th>Number of years in the pilot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ana</td>
<td>3rd-5th</td>
<td>2</td>
</tr>
<tr>
<td>Zach</td>
<td>3rd-5th</td>
<td>2</td>
</tr>
<tr>
<td>Kelly</td>
<td>Kindergarten-2nd</td>
<td>2</td>
</tr>
<tr>
<td>Jane</td>
<td>Kindergarten-2nd</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Grade Band</td>
<td>Number</td>
</tr>
<tr>
<td>-------</td>
<td>------------------</td>
<td>--------</td>
</tr>
<tr>
<td>Paul</td>
<td>3rd-5th</td>
<td>3</td>
</tr>
<tr>
<td>Sara</td>
<td>3rd-5th</td>
<td>2</td>
</tr>
<tr>
<td>Louis</td>
<td>3rd-5th</td>
<td>3</td>
</tr>
<tr>
<td>Lucy</td>
<td>Kindergarten-2nd</td>
<td>2</td>
</tr>
<tr>
<td>Beth</td>
<td>Kindergarten-2nd</td>
<td>2</td>
</tr>
</tbody>
</table>

**Procedures**

Upon IRB approval from Northeastern University, the researcher sought participants based on the record of teachers who have piloted the FOSS program in grades Kindergarten through fifth grade. The phase one participant recruitment letter (Appendix A) served as the tool for participant recruitment and was issued to all year one and two FOSS pilot teachers via the researcher’s Northeastern University email account. Interested participants were instructed to reply with interest to the researcher’s Northeastern University email account within ten days. Since the initial recruitment yielded nine participants, the phase two recruitment letter (Appendix B) was not sent to teachers in the first year of the pilot.

Participant selection for this voluntary study was determined with the intention of having at least four primary teachers (grades K-2) and four intermediate teachers (grades 3-5). The researcher would have considered utilizing a minimum of six participants of any grade band, but preferred to have a minimum of eight distributed among the two grade bands. The final participant pool consisted of nine participants, four in the primary grade band and five in the intermediate grade band. Due to the length of time per interview, including the transcription and data analysis, a maximum of twelve participants would have been permitted into the study with priority being given to those with the most experience teaching FOSS. However, at the
conclusion of the ten days, the researcher received nine responses of willing participants. Participants were notified of acceptance into the study (Appendix C) and no teachers to respond were notified of rejection to the study (Appendix D). Participants received an informed consent (Appendix E) form to sign at the beginning of the interview protocol (Appendix F).

**Data Collection**

Selected participants were contacted by the researcher’s Northeastern University email account to determine a date and time for the in-person interviews. Participants were asked to schedule a ninety minute period of time with the researcher at a location that was comfortable and convenient for them. Each participant was informed prior to and at the start of the interview that the interview would be recorded on two devices in case there were technical issue with one of them.

Phenomenology requires multiple participants because, by nature of the methodology, the aim is to make meaning from an experience that participants have in common. Phenomenology serves to describe participants’ understanding of their experience with a common phenomenon (Creswell, 2017), in this case teaching the FOSS kits. In order to obtain a rich set of data, the researcher collected data through one, three-part, semi-structured interview with each participant. The interview schedule was flexible, allowing for prompting and encouraging the participant to tell more of his or her story (Smith et al., 2009). Smith et al. (2009) warns that a quality interview is critical to IPA analysis and that while a prepared interview schedule may help shape the interview, it will not guarantee a quality interview. The researcher must engage with the participant, listen attentively, and probe to learn more about their experience and their understanding of it.
Creswell (2017) recommends two broad questions be asked in the interview: What have you experienced in terms of the phenomenon? What contexts or situations have typically influenced or affected your experiences of the phenomenon? The aim of an IPA study is to “say something in detail about the perceptions and understandings of this particular group rather than prematurely make more general claims” (Smith, 2015, p. 55). Therefore, it is imperative that the interview data provide the researcher with sufficient information to pull out the essence of each participant through as detailed narrative accounts as possible.

For the sake of efficiency, each recorded interview was sent to gotranscript.com for transcription due to the length of time it would take the researcher to transcribe each interview. The researcher reviewed each transcription for accuracy and then engaged in a process of member-checking, asking the participants to verify that the transcript accurately reflects the intention of their responses. The researcher sent the appropriate transcription to each respective participant via email (Appendix G) to ensure accuracy, allow for corrections, questions, clarifications, and additional information to be added to responses. Participant identity remained confidential and each participant was assigned a pseudonym and a number for the researcher to reference.

Data Analysis

One key difference between phenomenology and IPA is that the former describes the participants’ experience and the later inserts the researcher to interpret meaning from the description. The data analysis process in an IPA study is founded on thematic analysis, a process by which the researcher identifies, analyses, and reports patterns (Braun & Clarke, 2006). The data analysis process in an IPA study requires the researcher to fully analyze the first participants’ case prior to moving on to the next. When that process is complete, the researcher
can make comparisons between the participants’ cases (Shaw, 2010). The data analysis for this project followed the hermeneutic circle method of analysis by which the researcher engaged in a continual analysis of the parts and the whole of the data without bracketing out biases (Reiners, 2012).

The data analysis process involved multiple steps, each yielding new information and informing emergent themes, an inductive process by which the data determines the codes (Miles et al., 2014). Smith et al. (2009) assert that emergent themes will first reveal themselves in the individual cases and then across the cases. The researcher then inserts her own knowledge about the subject, making meaning through interpretation. The researcher employed a combination of the processes outlined by Smith et al. (2009) and Shaw (2010) to complete the data analysis process. After receiving the transcriptions from gotranscript.com and member-checking for accuracy, the researcher first familiarized herself with the data by reading and re-reading each transcript individually at least two times before moving on to the next phase of data analysis. During the familiarization process, the researcher listened to the audio while reading the transcript for the first time in order to recall tone and nuances in the participant’s voice as well and ensure that the transcription was conducted accurately. After reading through the transcript once, the researcher read the transcript a second time helping further familiarize herself with the data. The researcher then wrote field memos and a summary of her initial thoughts on the participant’s interview.

After reading twice for the overall meaning, the researcher moved on to reading the transcript a third time and making initial notes. The researcher examined each section of the interview closely and notated descriptive summaries as well as initial interpretations (Shaw, 2010) through the process of initial noting (Smith et al., 2009). The researcher notated
descriptive comments in the left margin, distinguishing between descriptive, linguistic, and conceptual comments in different colored ink (Smith et al., 2009) and added interpretations in the right margin (Shaw, 2010). From the descriptive notes and initial interpretations, the researcher began to develop emergent themes by shifting the data analysis from the transcript itself to the comments (Smith et al., 2009).

The researcher then moved from the initial noting phase to the development of emergent themes. The emergent themes reflected the participant’s words combined with the researcher’s interpretation and served to “speak to the psychological essence of the piece and contain enough particularity to be grounded and enough abstraction to be conceptual” (Smith et al., 2009, p. 92). This phase of process reduced the amount of data in that the researcher clustered notes and interpretations (Shaw, 2010), by searching for connections among emergent themes (Smith et al., 2009). Throughout the process of reducing data, the researcher highlighted important themes and discarded themes that did not pertain to the research question.

The process of identifying emergent themes resulted in a set of final themes for that individual participant. The researcher used the final themes to search for connections across themes through the process of abstraction (Smith et al., 2009). Smith et al. describe abstraction as “identifying patterns between emergent themes” by putting similar themes together and assigning them a new name for the cluster. The researcher maintained hard copies of the data analysis completed on the original transcripts and utilized conceptual maps to assist in the data management and analysis process. Field notes were utilized throughout to maintain an audit trail and provide justification for how themes connect to the original data set.

Once the clustered themes were finalized and connections made across themes, the researcher moved on to the next case (Smith et al., 2009) and repeated the entire process until all
participant transcripts were analyzed individually. The researcher bracketed out the themes unveiled in the previous data sets to the best of her ability so as to allow the themes and interpretations of each new data set to develop without bias.

Upon completing the data analysis process for each individual case, the researcher looked for patterns across cases (Smith et al., 2009). This process involved looking for similarities or connections among cases. It resulted in changing the names of themes so as to be more comprehensive and effective in describing the essence of the theme. The researcher utilized conceptual maps to assist in determining the most appropriate commonalities among the cases, thus resulting in a description of the common experiences of the participants. The results of the entire process are shared with the reader in a narrative presentation of findings in Chapter 4, leaning heavily on direct quotes from participants so as to richly illustrate the emergence of each theme.

Criteria for Quality Qualitative Research

Fink (2006) notes that the professional doctorate serves as the link between educational research and workplace problems of practice. The lack of time and attention dedicated to science at the elementary level is partially due to the lack of resources available to teachers. Rather than assume that the FOSS kits are manageable for teachers and effective in engaging students in science, it is important to develop a deeper understanding of the teachers’ experience with FOSS. Researchers must ensure that, “the changes they introduce are truly in the best interest of the student and not merely a matter of individual whim or personal convenience” (Labaree, 2003). This research project seeks to better understand how teachers describe their understanding of the impact of FOSS on their ability to engage students in science. Given the value of the study, several steps must be taken to ensure that the research study is credible, transferable, dependable
and neutral in tone and interpretation (Lincoln & Guba, 1985) while maintaining subject confidentiality.

**Ethical Considerations**

Throughout the course of a study involving human subjects, ethical considerations must be established to protect the participants and the data. The considerations for conducting an ethical study identified in this section come from Creswell (2013). Prior to conducting the study, the researcher obtained the appropriate approvals from the research site and through the Institutional Review Board (IRB) at Northeastern University. The researcher adhered to the policies on human subject research as established by the Northeastern University IRB. Participants were recruited on a voluntary basis and informed of the purpose of the study. Participants were provided with an informed consent form to sign prior to working with the researcher in any capacity related to the study. Participants were informed at the time of their acceptance to the study that their participation is voluntary and that they may exit the study at any point, for any reason. Since the participants are employees of the district, the acceptance letter also indicated that their participation in the study has no impact on their position in the district.

To further protect the human subjects, the researcher reminded participants of the purpose of the study and how the data obtained from their interviews will be used. The semi-structured interview questions were unbiased and avoided wording that may have lead the participants to a desired answer. The data analysis phase upheld the commitment to keep participants identity anonymous. Each participant was assigned a pseudonym and number and only the student researcher will have access to the actual identity of the participants. Grade bands, rather than grade levels were used in the written report so as to further secure the
participants’ anonymity. All data was evaluated during the data analysis process and all pertinent findings that addressed the research question were reported, including those that yielded negative results. Only the researcher and gotranscript.com had access to the raw data, although it was available to the researcher’s advisor and second reader if necessary. The interviews were recorded on two devices in case there was an error with one. The recordings were uploaded to the researcher’s personal, password protected computer and stored in a dedicated folder. Hardcopies of transcripts and associated notes pertaining to data analysis were stored in a locked file cabinet in the researcher’s home when not in use. Audio recordings collected over the course of the study will be destroyed upon publication of the study on ProQuest.

Credibility

Establishing credibility in a qualitative study is important because the data analysis is derived from an inquiry based process and interpreted by the researcher, unlike findings based on statistics as in a quantitative study. Patton (1999) states that credibility depends on three elements; a) rigorous techniques and methods; b) the credibility of the researcher; and c) a belief in the philosophical value of qualitative inquiry. Establishing clear procedures helps the researcher ensure the data analysis process is completed with integrity. The researcher conducted a three part semi-structured interview with each participant. The first part consisted of establishing rapport (Smith et al., 2009) with the participant by asking comfortable, easy-to-answer questions about their background and teaching experience. The second part directly followed part one and consisted of an in-depth semi-structured interview schedule.

After completion of the transcripts, the third part of the interview involved the process of member-checking. Each participant was provided with the transcript via the researcher’s Northeastern University email account. The participants were allowed an opportunity to
elaborate upon, make corrections, or clarify their words so as to ensure that their experience was captured accurately. Member-checking of the transcript and allowing an opportunity to clarify or elaborate on the transcript served to increase the credibility of the researcher’s findings.

Triangulation of the multiple data sources also lends credibility to the study. Triangulation was employed through the process of individual and group analysis of the multiple data sources obtained. The researcher’s field notes were referenced throughout the data analysis process. The researcher verified participant’s meaning of their interview responses through member-checking. Each participant was provided with the transcript of their interview and allowed the opportunity to approve, make corrections, or clarify any confusion. This process served to include the participant in a collaborative manner of verifying the findings and lends credibility to the study.

**Transferability**

Rich, thick description is a process in which the researcher paints a picture for the reader through the use of detailed descriptions of the participant’s experience and how a particular theme emerged (Stake, 2010). Tracy (2010), describes thick description as showing a reader, rather than telling the reader, how a conclusion was reached so that the reader may draw their own conclusions. Thick description may include quotes from the participant and rich descriptions about how general themes were narrowed to more specific themes (Creswell, 2013). The researcher used sufficient detail to describe the nature of the phenomenon so as to allow others to determine if the conclusions can be transferred to other settings or institutions (Lincoln & Guba, 1985).

In an IPA study, the researcher is focused on the idiographic nature of the participant’s account of their experience. After analyzing each participant’s case thoroughly the researcher
developed initial interpretations and final interpretations to attain some sense of closure with each particular case (Smith, 2004). The same process was followed with each participant prior to seeking “convergence” and “divergence” across cases. As the researcher moved from the data analysis phase to the write-up phase, she thoroughly described in great detail how a conclusion was reached, drawing directly from the data and relying extensively on direct quotes from the participants. The thick descriptions serve to provide readers with enough information about the development of themes to assist in determining how themes emerged.

**Internal Audit**

Establishing an audit trail is critical in proving that claims can be supported by and were derived from the data set. The audit trail is established and maintained throughout the data collection and analysis processes. The audit trail for this study included; a) the researcher’s familiarity with each individual case; b) the researcher’s descriptive narratives taken from the participant’s own words; c) the researcher’s initial interpretations and emergent themes; d) the researcher’s memos kept as field notes (Shaw, 2010); e) audio recordings; f) original transcripts; g) annotated transcripts; h) coding and conceptual maps; and i) the written report.

**Self-Reflexivity and Transparency**

Briscoe (2005) points out that, despite best intentions, a researcher has their own perceptions and intentions for embarking on a research study. Thus, the researcher’s representation of the participant will be from her own perspective. It is necessary to recognize one’s own perspective to develop strategies and techniques that aide in a credible data analysis process. This study sought to attain teacher perceptions about their experiences with a kit-based science program. As the Director of Mathematics, Science, and Technology in the district where the study was conducted, the researcher was aware that participants may view the researcher as
being in an authoritative position. The researcher has no formal supervisory capacity in regard to the participants in the pool of potential candidates. The researcher provides no written record of the participant’s professional performance nor does she have input into the tenure or employment decisions of any of the participants. The researcher informed participants that their participation in the study has no bearing on their position in the district.

The researcher has placed a tremendous amount of time into securing funding, training, and resources for the FOSS pilot. It should be noted that the researcher has a vested interest in seeing the pilot program work for the district. However, the researcher is committed to providing a meaningful learning experience to students and a resource that is manageable for teachers. The results of the study will influence the district’s decision to adopt the resource as a primary instructional tool. Despite the vested interest in the resource, the researcher was committed to adhering to the assurances in place to ensure that the study is credible and trustworthy.

Creswell (2002) explains that in a qualitative study the researcher is more in the foreground than a quantitative study. Because the researcher is present in the collection and analysis of the data, the researcher must take caution that the research is honestly reported and not influenced by personal interest. The acknowledgement of all of the potential areas of bias that could influence the research will serve to ensure that personal feelings about the topic do not influence the data. The researcher is a former middle school and high school science teacher and has developed a deep conviction in the need for high-quality, hands-on, elementary science instruction. One’s positionality has a direct impact on how one perceives and represents data gathered in a research study.

It is possible to be reflective about one’s positionality, acknowledge it, and then ground the research in theory. Nesting the study in a conceptual framework serves to minimize the
impact of researcher bias. Knowing that self-determined behaviors take time to develop, it is unrealistic to make a determination about the long-term effects of this study, therefore the researcher must acknowledge the process takes precedence over the product (Fennell & Arnot, 2008). Going into the study with that understanding helped to prevent researcher bias in knowing that given the small scope of the study, it is not intended to transcend into the entirety of factors influencing the implementation of science-kits. The researcher was merely focused on the experiences of a small group of participants, in one district, at a given point in time.

In order to separate personal bias from the data analysis process, the researcher; a) acknowledged that, despite the outcome, the study was intended to understand the experiences of the participants; b) reported all sides of the data honestly and with fidelity, relying on the audit trail to justify findings; c) remained true to analyzing the data while consistently recognizing biases so that the data remain pure; d) member-checked interpretations and conclusions with participants; e) utilized the support of her advisor and peer editor to verify that conclusions are supported by data and; f) acknowledged that the results do not allow for broad conclusions to be drawn about the correlation between FOSS use in Fairport and transferability to other districts.

**Limitations**

There are limitations to the study that may affect the research outcomes. The limitations included the theoretical framework, transferability, and the researcher’s interpretation of the participants’ experiences. Self-Determination Theory (SDT) is most often used in quantitative studies that analyze participant’s motivation. In this study, SDT was utilized as a lens from which to view teacher’s motivation to teach science based on their sense of competency with the subject. Secondarily, the teachers were asked to describe their perceptions of their students’ motivation and engagement in science based on the teachers’ instruction of FOSS. SDT deals
with motivation founded on the three primary tenets of competence, autonomy, and relatedness. The factor of relatedness is not addressed in the research question. The concept of autonomy is broached as a secondary factor in the study as interview questions targeted teachers’ sense of competence and autonomy to teach science. Given that SDT is founded on three primary tenets that each interact and influence one another, focusing primarily on competence may limit the findings.

This qualitative study was centered on one district and only a small representation of teachers in that district. FOSS has historically been a widely used program, the newly aligned Next Generation Science Standards version is being considered for adoption by other districts. This study may not be transferable to other districts in that the implementation model, level of training, and the district’s instructional day schedule flexibility may not be replicated in other districts. Additionally, nine participants were selected for the study and there are currently over eighty teachers piloting FOSS. The experiences of the representative sample included in the study may not transfer to the experience of all teachers implementing FOSS in their classrooms. The initial recruitment phase targeted teachers who volunteered to pilot the program during the first or second year of the program, indicating that they may be more apt to teach science, and confident in their science ability than those who did not volunteer for the pilot.

Finally, the researcher interpreted the experiences of each individual teacher-participant as well as the collective experiences of the group. The idiographic and personal nature of an IPA study by which the researcher works in depth with a group of individuals on a case-by-case basis is a limitation. The semi-structured nature of the interviews was also a limiting factor. Semi-structured interviews allow the researcher to stray from the initial interview questions, resulting in interview questions that are not identical. The researcher used the interview data to reflect the
experiences of the nine participants. The transferability of the factors that contribute to their experience are not replicable in another study. Despite the limiting factors, the researcher produced a valid, credible, and trustworthy research study that examined how a particular group of teachers described their understanding of the impact of FOSS on their ability to engage students in science.
Chapter Four: Findings and Analysis

The purpose of this Interpretative Phenomenological Analysis study was to understand how using the FOSS kits impacted teachers’ ability to engage students in science. Self-Determination Theory was utilized as the lens through which to interpret the findings. The research attempted to answer the question: How do teachers describe their understanding of the impact of FOSS on their ability to engage students in science? Nine participants, with experience in the FOSS program pilot, shared their experiences with the researcher. The analysis of the data generated three superordinate themes and ten subthemes.

The superordinate and subthemes are: 1) Teacher Confidence and Enthusiasm, 1a) Training, 1b) Content Knowledge, 1c) Readily Available Materials, 1d) Supportive Instructional Resources; 2) Student Engagement, 2a) Optimal Challenge, 2b) Dialogue, 2c) Real World Connections; 3) Hands-On Learning, 3a) Explore First, 3b) Challenging & Approachable Content, 3c) Deep Understanding. Table 2 provides a list of the superordinate and subthemes that emerged during the data analysis process, as well as the recurrence of each theme across the nine participants.

<table>
<thead>
<tr>
<th>Table 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification of Themes</td>
</tr>
<tr>
<td><strong>Superordinate Themes</strong></td>
</tr>
<tr>
<td><strong>Subthemes</strong></td>
</tr>
<tr>
<td>1- Teacher Confidence and Enthusiasm</td>
</tr>
<tr>
<td>1a- Training</td>
</tr>
<tr>
<td>1b- Content Knowledge</td>
</tr>
<tr>
<td>1c- Readily Available Materials</td>
</tr>
<tr>
<td>1d - Supportive Instructional Resources</td>
</tr>
<tr>
<td>2- Student Engagement</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
</tr>
</tbody>
</table>

**Teacher Confidence and Enthusiasm**

The first superordinate theme revealed in the study was Teacher Confidence and Enthusiasm. Each participant indicated that the FOSS resource increased their confidence and enthusiasm in teaching science. This was true of those naturally uncomfortable teaching science and with participants that already felt comfortable teaching science. Additionally, participants indicated that their confidence in teaching with the FOSS resource increased over time. The more experience participants had with the kits, the more comfortable they felt. There was also an indication that the overwhelming feeling of seeing the vast amount of materials subsided when they began instruction and observed the level of student interest, leading to increased enthusiasm to teach science.

Participants reported feeling more comfortable and confident not only with the materials and the layout of the resource, but with their instructional delivery and knowledge of the content. While each participant reported an increase in confidence and enthusiasm, some were more eager to dive in and teach each investigation whereas others were more hesitant; this tended to derive from their initial sense of competence in teaching science prior to piloting the resource. Both
those eager to begin and those more reserved expressed an increase in their level of enthusiasm for teaching science, primarily due to the response from the students, yet coupled with the fact that the materials and resources necessary to provide high-quality science instruction are right at their fingertips. The superordinate theme of teacher confidence and enthusiasm is divided into four subthemes which include training, content knowledge, readily available materials, and supportive instructional resources.

**Training**

Every participant indicated that training is a necessary and beneficial aspect when embarking on teaching with this resource. Each FOSS kit includes either three or four large rectangular boxes with drawers that contain all of the materials. Each kit comes with a student textbook component, a hardcopy teacher resource guide, and all of the text materials are available online along with prepared presentation slides for each investigation. Student journal focus questions and handouts are located in both print and online versions. The sheer volume of materials and resources were reported by some as overwhelming and intimidating.

Each participant, with the exception of one, who was unable to attend, received one half day of training with other teachers at their grade level on their specific kit. A half day, rather than a full day, was determined due to budgetary and scheduling constraints such as substitute costs and FOSS trainer availability. The intention of the training was to familiarize the participants with the materials and resources while providing access to the online and text aspects of the kit, background on the philosophical approach to the instructional delivery, and to allow the participants to actively compete two or three activities from different investigations. Also included was training on the organization of the teacher resource guide, how to access the online resources, and modeling of an actual lesson.
Additionally, ongoing, voluntary after school one-hour sessions were scheduled throughout the year so that teachers could work with other teachers in their grade level on planning, preparation, and to share success and failures. The results of this section indicate that the training is beneficial, that participants wished the initial training period was longer, that the initial training included more time for exploration of the activities, and that ongoing professional development continue to be offered. The participant unable to attend the initial training indicated that training is necessary and beneficial and has attended the ongoing after school offerings.

The half-day initial training was deemed helpful by each participant that attended, yet three participants felt as though their trainer appeared stressed or hurried and rushed them through too quickly without allowing time to explore. Those participants would have likely taken more from the training had they not experienced that situation. Each participant valued the time made available to go through the activities from various investigations. Kelly valued the training, stating:

It was just giving us time to look at what we were going to be doing. I feel like so much of what we get in teaching is learn on the fly, figure it out yourself and that's a huge missing piece because we don't have time to do that.

Even for veteran teachers confident in their science instructional skills, training was identified as important for the new resource. Louis felt the best thing about the training was the concept of “let's do a lesson that you're going to do in your room and I'll show you how it works." However, many participants expressed a desire to have a longer period of initial training in which they could dive deeper into more of the activities in each unit.

Paul would have preferred two or three days to thoroughly dig in and go through each activity to fully understand the components of it. Six other participants, including Ana and Sara,
wished for a longer initial training period such as a full day to try at least one activity from each investigation. Ana said that it would have been nice to actually do each activity, rather than just a sampling, so that she could say "okay, this is what I had a hard time with. Am I doing something wrong?" In addition to extending the length of time for the initial training, participants indicated a desire to have additional time available for exploring the materials and structure of specific investigations in their respective kits, rather than the instructional components such as how to use the word wall.

Each participant indicated the value of ongoing professional development to improve their familiarity with the content and resources as well as to talk with teachers who have experience teaching the resource. For instance Zach said it was helpful to “sit down with a group of educators that are doing the same thing and just bounce ideas off each other and have conversations as to what they're doing in their classroom and how they're using the kit is beneficial.” Several participants, including Kelly, Paul, and Lucy commented on how time to talk with others who have taught FOSS, regardless of the grade level, is helpful to share what each has learned and to ask questions if needed.

Working with colleagues provided an opportunity to offer advice as well. Jane dealt with the overwhelming feeling of the amount of content by keeping the teacher resource guide with her at all times and recommended this to teachers just starting out with FOSS. She described feeling robotic at first but explained that the instruction gets easier as you become more comfortable. Similarly, Lucy wanted to let teachers starting out with FOSS to know not to let the amount of resources scare them because the engagement and learning that takes place with the students is worth learning a new resource. The participants valued the ongoing professional
development time offered and noted that there is not enough time in the day to sit and talk with
colleagues about a new resource unless that time is provided and they make an effort to attend.

It is important to note that the instructional delivery components such as word wall usage,
student journaling, and discussion techniques are an important and critical part of promoting
deep contextual understanding. In the absence of the format of delivery, the investigations could
easily become “stand-alone” science activities. The desire for most of the participants to have
more exposure to the investigations in the kit appeared to be attributed to either an
uncomfortableness in trying something new with the class that was not vetted by the teacher, or
knowing that there was a lack of time to try them on their own after the initial training. It did not
appear that the desire for more time to explore the investigations was intended to mean that
training in the methods of instructional delivery incorporated in the resource are not important. A
recurring theme across all participants is the lack of time to prepare and plan. The initial and
ongoing training are perceived as beneficial because they provide that time and the time is with
colleagues whom they share the experience of implementing a new resource.

**Content Knowledge**

Participants were asked to describe their level of confidence in teaching science both
before and after the experience of using the FOSS kits. The teacher resource guide and online
components served to improve the confidence level in regard to the scientific content knowledge
for six participants. The teacher resource guide provides a “Background for the Teacher” section
for each investigation that provides a concise overview of the scientific context behind the
activities in each of the investigations to assist in the facilitation of the activities. The
background information is simple enough to read quickly and detailed enough to provide the
teacher with a comprehensive understanding of why the science works the way that it does.
Based on the reports from the participants the information in the background for the teacher section enhances the confidence level in the subject matter. Additionally, each sub investigation includes corresponding focus questions to guide student learning. The teacher resources guide is scripted, with prompts such as when and what students should pick to specific discussion questions with ideal responses to support the teacher throughout the lesson.

Although Kelly reported that the FOSS resource has helped her feel more confident with the science content knowledge, she also stated:

There's definitely that piece of, I don't really have the background knowledge, I’m learning it as I go. But that is in a way a powerful experience because I’m learning it with the kids and I’m having those moments too.

Similarly, Jane described her preference to constantly hold the teacher resource guide in her arms while teaching the kit the first year. However:

Last year was much better because I wasn't holding the manual or running back to it quite as much. I'd look over and see and I could lead into whatever an answer would be; we would discuss that a little bit further.

Kelly utilized the teacher resource guide as a tool to provide the content knowledge as a lesson progressed because she was uncomfortable with her level of knowledge in the topic. Jane and Sara, however, tended to keep the resource guide with them as a means of maintaining focus so as to ensure the purpose of the lesson was achieved without getting too far off topic by the many student conversations. Each felt more comfortable with their level of content knowledge going into their next year teaching the kit regardless of the initial purpose for utilizing the resource guide heavily.
The background information for the teacher provides a broad overview of the scientific concept and the specific scientific context upon which each activity is structured and the resource guide then provides an organized layout for the delivery of the lesson. As Sara described:

It's so helpful to have that background for the teacher and then I'm not having to quickly Google things just in case there's a question. Sometimes you get questions that are above what the lesson is really about, and to have that at my fingertips is ridiculously helpful.

The organization of each investigation is the same and provides teachers with detailed setup instructions, tips on how to utilize the students to help, scripted statements to introduce the activity and discussion questions. While teaching the lesson, the teacher can pull up the prepared presentation slides to use simultaneously. These combined components provided, even participants that felt confident in their content knowledge at the outset to feel an increased sense of confidence. For example, Zach, stated, “I feel like this does a much better job of explaining what we're doing and how we're doing it. I think the fact that the teachers have the resources, it allows us to improve our knowledge of that topic.”

Lucy, who did not identify as a “science person”, attributed “that beautiful explanation of what the science actually is” to her increased sense of confidence in teaching science using the FOSS kit. She went on to say, “Now I have a much better understanding that helps me when they ask those guiding questions, like where they need to go; what they're learning. I feel much more confident and competent as a science teacher now.” The online component also includes teacher preparation videos that shows the set-up and a demonstration of each activity while explaining the science behind it. Ana expressed that she accessed the videos if she did not feel knowledgeable about the content, which was helpful to build her understanding prior to teaching
the unit. Paul also noted that while he does not often need to consult the teacher preparation videos, he has on occasion when reading about the setup did not resonate.

Three of the participants did not indicate that the resource had an impact on their content knowledge of the scientific concepts. Each of the three identified as a “science person” confident in their science content knowledge. Even though Louis is comfortable with science content in general and did not indicate that the resource impacted his content knowledge on the subject matter, he did note increased enthusiasm to teach science:

I would say, it makes it more fun for me and more enjoyable because there's more things that I can try or do or model and show them. Them giving me those resources, to say, ‘Try this or show them that’, that's great. Whereas you might not think to do those things on your own.

Paul described a similar experience to Louis. Beth did not indicate an increased level of content knowledge due to the use of the kit, but also explained that it was an early primary level kit in an area of science in which she felt comfortable.

Regardless of whether teachers utilize the instructional resource guide as a tool to provide them the content knowledge in the moment, or if they use it to maintain focus on the content, it served to increase confidence in the content knowledge. Based on the experiences of the participants, teachers do not have to be experts in the content area to find success with the FOSS resource. There are an abundance of resources provided to support the acquisition of content knowledge for novice teachers and those uncomfortable with teaching science in general.

**Readily Available Materials**

In the drawers of the storage boxes, each FOSS kit is equipped with the materials needed to conduct each activity in the hands-on investigations. Students are expected to work in partners
or groups and there is enough of the larger equipment, such as balances, for each group and enough smaller materials, such as magnifying glasses, for each student. There are enough consumable materials to teach each investigation at least three times before refurbishing. Several participants noted that they did not use anywhere near all of the consumables and that the refills likely do not have to occur yearly, even for those that shared a kit. Each participant indicated that a strength of the kit was the readily available materials. The materials were reported to be of high quality, functioned well, were easily stored, and that everything needed for an investigation was easily accessible. It should be noted that one participant reported dissatisfaction with one of the pieces of equipment in one of the kits as it was difficult for the students to manipulate and the design impeded functioning. Participants such as Ana commented on the ease of use of the materials included in her kit and compared them to a former kit-based resource on the same content that was much more difficult for the students to manipulate.

The storage of materials was a positive aspect of the kit for Ana, Kelly, Paul, and Lucy. For example, Kelly states:

I loved the way that they were pre-packed, pre-done. It was a little hard when you first start. You feel overwhelmed because they were in there but they weren't organized in the way you need them to start. Just getting the time to pre-set the base before each lesson was a lot. Once you get doing it… ‘Oh, this isn't so bad’, but that time commitment. You needed to get it out all ahead of time.

Paul said, “They have literally given you everything that you need. They say teacher supplies, it’s like tape or something you have.” Lucy agreed, and stated:

The pros is that everything is there. I don't have to go try to find plastic cups. I don't have to go try to find whatever I need to do the experiments. It's all there and provided and
labeled. The con is, it does take some prep to get everything ready for it in finding the right (materials).

Despite having unanimous positive responses for the accessibility of the materials, the negative aspect was the feeling of being overwhelmed by the sheer amount of materials and preparation, as indicated by seven of the participants. Zach described the feeling of sorting through and preparing the materials as much more time consuming at first than the actual amount of time spent teaching the lesson. A recurring theme throughout was the participant’s acknowledgement that while the materials took up precious classroom space, it was beneficial to have them readily available. Not needing to go purchase materials or look up activities and find materials to deliver a quality science lesson was an overwhelmingly positive aspect of the kits. The participants felt more comfortable teaching the lessons knowing that the materials were readily accessible and that they worked well. The materials also increased some of the participants’ enthusiasm to teach science because of the reaction from the students. For example, Paul described:

Just the mere sight of that bin on the table when they walked in the room, they were ecstatic. Their eyes lit up. The old days, it was, ‘Take some notes,’ and have a quiz, ‘Here's the picture of the body or something.’ Now they know they're going to be doing some stuff.

**Supportive Instructional Resources**

The instructional resources included in the kits refer to the teacher resource guide, the online teacher resource guide, additional online materials such as teacher preparation videos, electronic blackline masters, prepared presentation slides, and student resources. Each participant indicated that the instructional materials provided increased their confidence in
teaching science, even those participants that identified as confident in their ability prior to using the kits. The materials were well organized, available in multiple formats, and supported the science instruction. The instructional resource provided some participants with an increased sense of comfort in trying new activities. The background information for the teacher coupled with the organized and structured layout of the lessons increased Ana’s comfort level. She stated, “If there wasn't as much information for me to be able to read, I would be a little more cautious about trying more of those activities.” Lucy expanded on the notion of trying new activities when she described the supportive nature of the instructional resource:

Makes it very easy to give the kids a really hands-on engaging experiment because it's all there for you and I don't have to think through and wonder like, ‘Oh gosh what should I, how could I approach this topic’, it's all written right there.

During the delivery of instruction, each participant indicated that they utilize, to some extent, either the teacher resource guide, the whiteboard slides, or both. The teacher resource guide served as a tool to increase confidence in the delivery of instruction, such as in Sara’s description of keeping the “teacher guide with me during a lesson just in case because, actually, I love how it even says the questions that you're going to ask and then it gives you the expected answer in parentheses next to it.” Paul stated, “the whiteboard slides follow along with the step-by-step instructions. I always use that resource with my investigation tab and just everything you need is right there.” Sara followed that approach and also made sure to have the student materials copied ahead of time to hand out when she reached that slide in her lesson.

The participants noted an appreciation for the multiple formats in which the instructional resources can be found. Everything in the teacher resource guide can be accessed from a web-based site. All of the handouts and items to be copied from the teacher resources can be found in
online format so that teachers can send directly to the copiers from their classrooms. As Sara described:

Everything that you need is either on the online component, you can print out the assessments that kind of thing there, but it's also in the teacher book, my master book too. There's many different ways to find it, for some reason something's not working with technology you have a backup too, that's great.

Louis, who described himself as confident in his science teaching ability appreciated the step-by-step nature of the instructional resource. He felt comfortable utilizing the detailed directions and online components when they were beneficial to his instruction, and then also modifying those structured resources to make them his own by integrating more English Language Arts, math, and quick custom assessments. The detailed descriptions included in the resource can be cumbersome to some at times because they provide so much information. For example, Jane described the specific steps outlined in the teacher’s manual to distribute and collect resources, and then added that many experienced teachers probably do not need directions quite so detailed. She indicated frustration with trying to decipher what was necessary and what she could disregard during her first year of utilizing the resource.

Conclusions

The superordinate theme of teacher confidence and enthusiasm was divided into four subthemes including; training, content knowledge, readily available materials, and supportive instructional resources. Each subtheme contributed in some way to an overall sense of increased confidence and enthusiasm in teaching science. Training was deemed as necessary and beneficial both initially and ongoing. Training was reported to be most beneficial when it provided time to explore the investigations and to collaborate with colleagues. The resource increased the content
knowledge about the subject matter for seven participants. Those unaffected identified as being knowledgeable about science and one taught a kit at an early primary level. Those that indicated an increase, attributed it primarily to the scientific background knowledge provided and the online videos. Each participant indicated that the readily available materials and the supportive instructional resources as factors that contributed to increased teacher confidence and enthusiasm to teach science. The participants appreciated that the materials were high quality, functioned properly, and were all easily accessible. The instructional resources supported the teachers in effectively utilizing the materials and the content knowledge to deliver quality science instruction.

**Student Engagement**

The second superordinate theme revealed in the study was Student Engagement. Each participant indicated that the FOSS kit resulted in the student’s being engaged in their learning. This was true for each participant regardless of their level of experience and confidence in their science instructional ability. Each participant referenced the high level of excitement and interest observed in the science learning. The FOSS lessons sustained student interest and engagement with little prompting from the participants. The superordinate theme of student engagement is divided into three subthemes which include optimal challenge, dialogue, and real world and content connections.

**Optimal Challenge**

Optimal challenge refers to the content of the lessons challenging students while allowing for student success, regardless of the student’s skill level. Eight of the participants indicated that the lessons were structured in a way that challenged students’ and concurrently allowed for success for all students. The result was described as sustained student engagement and interest in
the learning activity without excluding students who had difficulty understanding the depth of
the content. The exception was Beth, who taught an early primary unit and felt that there were
some students who did not understand the underlying scientific concept, did not absorb the
pertinent aspects of the hands-on activities, and struggled with the written portion of the unit.
Components of the characteristic optimal challenge were described as allowing some level of
success for all students, appropriate content and reading levels for the grade level, and an ability
to scaffold the learning to reach multiple skill levels.

The notion of challenging content allowing success for all was summarized by Ana as,
“it's not to the point that it's so above what some kids could do. Everybody is able to be
successful.” While the content allows for success for all students, the participants did not indicate
that the content was too easy. Eight of the participants described the content as being challenging
to students, yet approachable. For those students able to understand the concepts and go deeper,
there is opportunity to enrich. For the struggling learners or students new to the English
language, the hands-on component allowed for success and understanding of the concepts even
if it did not fully translate to the written components. For example, in regard to the content, Kelly
said it is:

Definitely challenging. I do think allowing for success too, because of the hands-on
piece. Kids are still getting to explore the materials. Whether or not they're able to write
about it after, that's not really defining success in the kids as much, which is good.

Prior to teaching the unit, Jane and Lucy initially thought that the content appeared to
look too difficult for the students. Despite thinking the content may have been too difficult, Jane
realized that the students are:
Not frightened or intimidated at all anyways and, again, that's more of a credit to FOSS that they are asking very appropriate things out of the kids to do at this level, there's nothing that's upsetting them. We're not putting them on the spot to answer and report all these questions or thinking without having lots of group talk and group explanations and hands-on stuff first.

Lucy contributed that the hands-on activities promote an opportunity to teach acceptance of failure at the early primary level and to help students push through challenge rather than fear it. Paul felt similarly about his students in the intermediate level, stating that they better understand that failure is part of the scientific process.

The participants expressed an appreciation for the content being scaffolded in a way that allowed them to reach multiple skill levels in their instruction. Sara noted the ability to enrich the activities for the gifted students and for the students that quickly understood the topic at hand, while also allowing them free time to explore the materials to create their own problems, which the students enjoyed. Lucy described the assessment, or comprehension questions, as valuable for the teachers to ascertain the student’s level of understanding of the topic:

They ask them what they think. They can't just answer yes or no. They have to explain their thinking a little bit. That's where asking the same question over and over again, helps to really solidify their thinking because they have to keep returning to that and explain, adding the new knowledge that they gained.

The scaffolded approach to the content was reported to promote independence as well, providing more opportunity for the teacher to differentiate. For example, Louis said:
Some groups are really on. They have confidence, they want to do it so then you can give them less direction and say, ‘Go, see what you can do’, and then others I can focus more on. That’s a good way just to differentiate for them.

There was a distinct difference between the challenges of writing at the early primary levels that seemed to remedy itself by the second grade experience. As Beth described the writing:

It was just way too hard for them. I couldn't use the journals. I really had to pick and choose what I was using and kind of pare it down…I did skip some of the writing things, like I said, because they are just too much for my kids.

Lucy, another early primary level teacher commented, “The journal, the writing pieces, I was nervous about. They love it. They love writing what they've discovered. I had to make some adaptations because they're just not good writers yet. The physical writing is difficult”. Beyond first grade, no participant indicated a concern with the challenge of the writing component being too difficult for the students.

Challenge, in the sense of student engagement, was not defined by the participants as success, or at least success in the traditional sense of mastery on a paper and pencil assessment. Challenge, according to some of the participants refers to challenging the student to learn more about the scientific concepts of the topic of study than they knew before. Optimal challenge meant allowing those able to go farther to do so while also challenging all students to push their level of knowledge without feeling inadequate. The optimal level of challenge appeared, as reported by most participants, to have contributed to a sustained level of student engagement and interest in the investigations.

Dialogue
Seven of the participants noted that the inherent design of FOSS, requiring student collaboration, increased scientific vocabulary usage, on-task talk during the activity, and increased student communication skills. Jane described how the materials served as a contributing factor in increased student collaboration:

I think the thing with the kits that's nice is not only are they working together but there's enough materials that even when they're working together they don't - it's not like they're sharing just one magnifying glass. There's enough for both of them to each have one but talk with each other there so you have somebody to bounce ideas and thoughts off of, but you're not just sitting there the whole time waiting for your turn.

Sara and Louis echoed the sentiment that students actively “doing” and not sitting back, is a contributing factor to the increased level of collaboration.

The student collaboration is an intentional aspect of the FOSS design. According to Louis:

There’s not one activity where you can do it by yourself. When they work in their journals they sit near each other, so if they get stuck they can say, ‘How are you going to write this?’ ‘How are we going to talk about this?’

Zach expressed a similar observation, “I think that they become better communicators over the process of the unit, especially if you keep the groups the same because now they're used to working with that group and they're used to communicating with them.”

Several participants described the classroom environment during a FOSS activity as noisy and busy. Sara joked that if someone walked in the room during an English Language Arts activity they would likely hear some groups talking “off-task” but that during FOSS time the group conversations are occurring but they are “on-task” talk. The students have learned that,
“talking in school is not a bad thing. They don't see it as a bad thing. It's a way to learn. They learn more from each other than they'll ever learn from me”, stated Paul. Lucy described the classroom environment during a typical FOSS lesson as:

Noisy. They're excited, but nobody's off topic; they might be silly, but we've set some protocols about what our expectations are. It's busy. It's exciting. They can't wait to tell each other. They're talking. They're writing. It looks really busy.

An increase in the use of scientific vocabulary, both during FOSS activities and outside of science time was observed by several participants. For example, Ana said, “It became the norm for them to be throwing in different scientific knowledge or scientific vocabulary”. Sara noticed that the students tended to utilize the word wall with the vocabulary word frequently at first, but then, “you actually see where they're not needing that word wall anymore and they're using the words pretty freely in their vocabulary. That's a big indicator for me too that they're really getting it and engaging with the material.” Paul attributes the increase in vocabulary to the fact that the students are “now able to talk about what they are doing”, meaning that they have a reason to talk with peers because they need to for the success of the group and because they have a common experience to talk about; the activity at hand. Sara describes this phenomena as:

They're all just really doing it, there's not somebody leaning over in the back, checked out, they all are actively participating in the experiment, they're all writing it down. Then you also hear that buzz of science vocabulary terms floating around the room which is great.

The two participants that did not indicate student dialogue as a contributing factor to student engagement had somewhat different experiences that the other participants, both involving language barriers and content deficits described earlier with their particular
populations. The remaining participants described a positive impact on student dialogue including increased scientific vocabulary usage, on-task talk during the activity, and increased student communication skills, due to the implementation of the FOSS kit. Students continued the dialogue outside of the school as described by Louis as student conversations about the science on the way to the bus, or Sara when a parent informed her that her student couldn’t stop talking about the science topic at hand at the dinner table. The student dialogue, both in and out of class, is a sign that the content and activities are engaging to the students.

**Real World Connections**

Each of the participants specifically referenced the real world connections that students made during their scientific discovery. The real world connections described can be divided into the categories of application of knowledge, relevance to daily life, and connections to careers. Lucy described how the activities in the FOSS kit require students to apply what they have previously learned from their investigations to the current learning activity. She stated:

I really liked that because they helped them draw conclusions that they might not have come upon or that I might have in the past. It might have been stated to them instead of them experiencing it. It was really powerful.

Paul also felt that students taking ownership of their learning, coming to conclusions on their own is a powerful part to sustaining engagement. He said that teaching them problem solving, rather than giving them the answers, also leads to a deeper understanding of the content. He went on to say that the resources and materials provided in the kit makes it easier for him to provide that engaging experience to the students.

Some teachers allowed the students to utilize the materials at their own leisure either after they completed the assigned activity or during a free period of the day. During free time, Zach
observed a group of students utilize the materials in the kit to design and execute a lamp for the inside of a classroom desk. Several students worked together on a problem of their making. Kelly provided an example of how excited the students were to bring in objects relating to the kit they studied into the classroom to put on display for others to see. She could not believe how interested they were in the topic and for such a lengthy period of time.

The real world connections extended beyond the students’ daily lives to potential career fields. At the primary level, Beth described the students’ excitement to “be scientists” while using a magnifying glass and clipboard to make observations. At the intermediate level, Sara described the intrigue as students began to understand what an engineer does and how an engineer works with scientists to develop solutions to problems. Behaving like a scientist or engineer in the classroom appeared to appeal to students and contribute to their engagement in the lesson.

Conclusions

The superordinate theme of student engagement revealed three subthemes; optimal challenge, dialogue, and real world connections. Whether the students were applying content knowledge to solve their own problems, connecting the learning to a relevance in their daily lives, or making connections to careers, the participants all felt that the FOSS kits contributed to student engagement in the form of real world connections. Overall, student engagement was reported to be a positive outcome for the implementation of the kits. Participants attributed the student engagement in part to the optimal challenge that the kits provide, sustaining interest by allowing for success. Additionally, the intentional peer collaboration was reported to increase and enhanced student dialogue, both in peer conversations through “on-task” talk and vocabulary
use. The final subtheme of student engagement spoke to the real world connections students made to other content areas and to life outside of the classroom.

**Hands-On Learning**

Every participant indicated that the hands-on aspect of the kits was both their favorite part of teaching science with this resource and the students’ favorite part of the instruction. Students were allowed the opportunity to learn through the exploration and self-discovery process, rather than being spoken to about what is important. A positive aspect of the hands-on learning was that the teacher did not have to actively work to engage the students. They were naturally engaged in the learning. The superordinate theme of hands-on learning is sorted into three subthemes, including: explore first, challenging and approachable content, and deep understanding.

**Explore First**

The hands-on learning was a favorite part of the kit for the teachers, and they believed for the students as well. While the time and preparation involved in planning and setting up the activities was described as daunting, the participants also noted that it was worth the effort because the students loved the hands-on aspect of teaching science with the FOSS kit. The organization of each investigation flips the traditional model of read and then possibly do an activity. Rather, the kits provide students the opportunity to explore with the materials first, work with partners to solve a problem, grapple with the vocabulary, make predications, and then go to the textbook to learn the science behind the activities. Zach said, “They're expected to do it and figure it out on their own. Then the nice thing is we go back in the book and it explains to them exactly why things work that way.”

Lucy described the difference of the “explore-first” method to a traditional method:
Traditionally, you're given a textbook. They're going to read about it. They're not going to experience or put together an experiment or there might be a picture of the experiment in a textbook. They have to imagine what would have happened in that experiment.

Where this is entirely different. Pose a question, let them experience it, and then another set of questions that are about that experiment that they participated in and actually did with their own hands.

Jane had a similar take on science instruction using a former resource:

They were allowed to touch them and talk about it, it wasn't just quick touch it, we got two seconds and now I'm going to take it away and you're not going to see it again and that's it.

Alternatively, the science instruction with FOSS is designed to be primarily hands-on experiences in which the student explore first and develop their own understanding prior to going to the text resources. Students’ journal while working, are encouraged to draw pictures, and are grounded in a focus question that guides their hands-on work.

Exploring with the materials first was not solely described as beneficial for sustained student engagement. Participants described this method of learning science as beneficial to developing background knowledge from a common experience and providing a greater senses of competence in their scientific acuity. Beth said that the explore-first method has changed the way she thinks about science instruction. She has learned that doing the activity and then writing about it rather than “front-loading” the content helps the students develop background knowledge first. Similarly, Louis felt that exploring first challenges students to use the vocabulary differently, and that seeing the words on the word wall, “helps them with their competence” because they are familiar with the vocabulary by the time they go into the textbook.
The students have already used the vocabulary words in conversations about the hands-on activities so they mean more to them than simply reading about them for the first time without context.

Ana and Kelly did not express the theme of “explore first” in their interviews, however they both spoke at length about the benefits of the hands-on activities and both felt that the hands-on aspect was a strength of the kit. Neither explicitly linked exploring prior to the text instruction as a strength. While all of the participants noted that the hands-on aspect of the kits were a strength and positively contributed to student leaning, seven connected the exploring first model to a deeper level of engagement and student understanding of the scientific concepts. Students make their own connections, take ownership of their learning, have extended periods of time with the materials, and make deeper connections to the concepts when they are formally introduced after the activities.

In addition to the positive feedback about the explore-first concept, the participants felt that the hands-on aspect of the instruction had other positive outcomes. “They're not being told what to do. They're not being told exactly how things are”, stated Zach. Sara had a similar perception, “They just get so excited about it and being able to be the boss of their own learning, those days that they get to come up with their own focus questions, they could not be more into that.”

Zach attributes this to the exploration aspect of the hands-on learning:

I think it's just how it's set up. The fact that these kids are having fun while they're learning, they're problem-solving. That takes the engagement piece off of me. I'm not trying to build it up and make it seem fun because they're the ones that are creating these experiences. They're the ones interacting with the kits and enjoying it.
Kelly described a similar experience, “The hands-on hands-down is their favorite…They love it. They would do that all day every day if we could.” Sara noticed that the hands-on aspect of the learning helped to engage students that are turned off from other aspect of schooling:

It might even be tough behavior management kids, that kind of thing; if they can be controlling what they're looking at, what they're going to be learning that day, that makes such a huge difference. It's one more piece of the day where it's not somebody else telling you that this is what you're going to do now, that makes a big difference too.

The hands-on aspect was reported by most of the participants to be effective not only in that the students are engaged with the materials, but that the take ownership of their learning. For example, Lucy appreciated “how hands-on it is. I love that the kids get a chance to really set-up the experiments. It's very clear for a teacher to help guide them do that.” Louis had insight into why he thinks the hands-on aspect contributes to a deeper understanding of the content:

I want to say, these science kits are more body-kinesthetic. They're more- we do the lesson and then we get up and we're moving. They're constantly moving, thinking, on the ground, measuring, and they have to work with each other.

**Challenging and Approachable Content**

Earlier the theme of optimal challenge was described as it related to student engagement. The theme of challenge also emerged in the context of challenging, yet approachable content. Meaning that the structure of the FOSS kits provided sustained interest and engagement in science but also provided learners on all areas of the continuum of learning with a challenging yet attainable contextual understanding of the scientific concept addressed in the kit. Every participant noted that the hands-on learning resulted in challenging yet attainable content.

Students who struggle with reading, writing, or the English language found success with the
science content through the hands-on experimentation. Students that were ready for a greater challenge could be pushed farther or allowed to explore and generate their own deeper learning opportunities based on the content being studied.

Several participants, particularly those who teach in an inclusive co-taught setting, or with a large population of English as a New Language students mentioned the difficulty that some students had with the reading or writing sections of the program. However, each that expressed concern also stated that the hands-on component was accessible and that, even though the students may not be able to fully demonstrate their learning via writing, they did know that the students learned science content. When Kelly described the difficulty that English language learners had with the kits, she said “The hands-on they light up, they can keep up, they can watch. They're great at watching what the kids are doing and doing the process. But, it's like the written piece for sure (was difficult).” Sara described the difficulty that some students had with the reading or writing component of the activities and recommended pairing up students of different reading levels to help remedy the problem since so much of the FOSS resource requires partner or small group work anyway.

Most of the participants noted the focus question for each investigation as a strength of the kit. However, Ana explained that some of her students did not like the focus questions because they required the students to write using the vocabulary words and that the students would have preferred to just do the hands-on components. That response was not common, for example, Sara noted that her students loved writing in their journals. Other participants, such as Jane, noted the challenging content as not being, “way above and beyond but definitely made them have to solidify their thinking a little bit more and put it into words.” Others, like Lucy, thought after reading the teacher resource guide, “I felt like it sounded like might be a little bit
too hard to grasp for (early primary students). But it was approached in a way that was so accessible that they really got the understanding.”

Louis, described opportunities for reaching multiple skill levels:

You could go as deep as you possibly can with the material that we have, or just scratch the surface… You can just skim the surface nice, and get them some basic background knowledge. Once they have that, you can go even deeper and talk about engineering.

Beth thought the content went, “pretty in-depth. It started very basic… which I felt built the kids' confidence so that they were more apt to get into it.” Kelly explained that while some content was over the heads of some of the students in the class, it did not make those students feel excluded. Sara felt similarly and felt the resource allowed for the teachers to enrich and go more in depth for the students that were up to that challenge. The hands-on aspect of the kits were reported to provide students with a challenging yet approachable learning environment.

Deep Understanding

The hands-on learning, which is the foundation of the FOSS kits, was reported by eight participants to result in a deeper understanding of the scientific content. The one participant that did not identify the deeper understanding taught an early primary kit that included a subject matter that included far fewer manipulatives than the other kits in the pilot. That kit has since been removed from the pilot. The theme of deeper understanding indicates that the participants felt the kits promoted independence to take the learning deeper, rather than just on the surface, which resulted in a belief that the students learned more about the concepts and in a more authentic manner.

“You can just see their excitement and their energy to further their understanding of the concepts that they're doing”, explained Ana. She went on to say that the students would extend
the lessons on their own because, “once they were successful at one part they'd say, ‘Oh, I wonder what happens if I do this’ and then try it”. Sara described the content as, “pretty deep but it's not overwhelming. Each lesson will build upon the other, and it looks for a deeper understanding than just the surface level” such as the expectations of other science resources she has used in the past. For example, in describing an activity in her kit which required students to create their own activity for the class, “it was amazing to see the plans that the kids made, how scientific and how exact they were going to be with keeping track and using those measurement skills. That is the whole point of it.” Several participants described a similar experience, by which the students, without prompting, elevated their expectations for scientific accuracy via trial and error. Kelly described her shift in thinking as she observed the students:

For me, part of it was stepping back and realizing they're learning even if it doesn't come out in the written way that maybe we're used to. You're amazed at the depth of what they learn and how much they enjoy it.

Lucy attributed the depth of learning to the structure of the lessons:

It’s like an inquiry. To help them focus their learning and try to figure a problem out. I really feel like they did a great job with that. At first, I felt they were repeating that question too often. I'm like, ‘Gosh, they're going to get it’ But I discovered that kids really needed all that time. They needed the question repeated over and over again.

She went on to explain that the repetition of the question grounded the students in coming back to the one simple “why” of the lesson. After each exploration and the acquisition of new learning, they were able to expand on their answers to the same question. Paul also appreciated that format and the independence that it provided the students. He said, “It's never me telling them what to put in there (the journals). It's not me giving them notes. It's them seeing it, taking
notes” and asking questions of one another. He described that hands-on learning was much more meaningful than providing them the answers or telling them what the expected result of a lab should be. Louis contributed some of the deep understanding to the kinesthetic aspect of the learning experience. “I think they remember a lot more because while they’re moving around, their endorphins are going, their brain's pumping, their blood's pumping and they’re having experiences as opposed to desk, pencil, reading.” Kelly summarized the hands-on student experience and compared it to her own learning:

The depth that I see them not just learning it, but really learning it well. I like that about it. I think if I were to learn it and learn it as well as they did, my science childhood experience would be different.

Conclusions

The superordinate theme of hands-on learning was divided into three subthemes; explore first, challenging and approachable content, and deep understanding. The power of hands-on learning was a resounding theme among the participants. Allowing students to explore first and then follow up with the text, combined with a challenging yet attainable curriculum, was described as leading to a deep understanding of the scientific content. The participants reported the hands-on aspect of the kits to be one of the strengths, not only in fostering student engagement but in providing a deeper level of understanding of the content matter. The hands-on approach provided students time to explore the scientific concepts with peers in a non-intimidating format.

Conclusion

The purpose of this study sought to understand how using a kit-based science program impacted teachers’ competence in engaging students in science. Nine participants volunteered for
semi-structured interviews to share how they made meaning of their experience with teaching the FOSS kits and how that experience impacted their ability to engage students in science. This chapter presented the findings of the participants’ responses to the research question: How do teachers describe their understanding of the impact of FOSS on their ability to engage students in science? An interpretative phenomenological analysis of the data revealed three superordinate themes and ten subthemes.

The findings and analysis of the study reveal that all participants unanimously indicated the three superordinate themes as integral aspects of their science instruction utilizing the FOSS kits. The superordinate theme of teacher confidence and enthusiasm was influenced by the subthemes of training, content knowledge, readily available materials, and supportive instructional resources. Each of the participants expressed that their level of confidence and enthusiasm increased due to one or more of the subthemes. The second superordinate theme of student engagement was attributed to the subthemes of optimal challenge, student dialogue, and real world connections. The participants observed a high level of sustained student engagement and interest through their use of the kits. They attributed the engagement to challenging, yet attainable learning activities and observed an increase in the use of vocabulary and communication with peers as well as real-world connections to the content. The third superordinate theme of hands-on learning was categorized into the subthemes of explore first, challenging and approachable content, and deep understanding. The hands-on foundation of the earning activities allowed for students to explore with the materials for extended periods of time while problem solving challenging yet approachable content, which resulted in a deep level of understanding of the scientific content.
Chapter Five: Discussion and Implications for Practice

The purpose of this qualitative study was to understand the impact a kit-based science program had on teachers’ ability to engage students in science. Nine participants, with experience teaching the kit for at least one year in grades Kindergarten through fifth were interviewed. The Interpretative Phenomenological Analysis (IPA) research methodology was employed to allow the participants the opportunity to describe how they made meaning of their experience utilizing FOSS. The research attempted to answer the question: How do teachers describe their understanding of the impact of FOSS on their ability to engage students in science? The IPA approach allowed the researcher to gain an in-depth understanding of how the participants viewed their common experience and to make meaning of the similarities and differences among their experiences.

Self-Determination Theory (SDT), developed by Deci and Ryan (1985) served as the lens through which to make meaning of the participants’ experiences. Through the data analysis process as outlined by Smith et al. (2009), the researcher identified three superordinate themes and ten subthemes. The superordinate and subthemes are: 1) Teacher Confidence and Enthusiasm, 1a) Training, 1b) Content Knowledge, 1c) Readily Available Materials, 1d) Supportive Instructional Resources; 2) Student Engagement, 2a) Optimal Challenge, 2b) Dialogue, 2c) Real World Connections; 3) Hands-On Learning, 3a) Explore First, 3b) Challenging & Approachable Content, 3c) Deep Understanding.

When combined, these themes serve to answer the research question. Participants observed a high level of student engagement, attributed primarily to the challenging, yet attainable hands-on approach of FOSS. It cannot be conclusively stated that FOSS increased the teachers’ ability to engage students in science, even though the students were reportedly
engaged, because students may have been engaged due to the hands-on aspect rather than the teacher’s skill in engaging them. Teacher confidence and enthusiasm for teaching science increased through the use of FOSS and participants reported a belief that the students attained a deeper level of understanding of the scientific concepts.

This study adds to the existing body of literature in that, to the best of the researchers’ knowledge, there are no existing studies that examine the general effectiveness of the NGSS aligned FOSS kits across multiple grade levels and various disciplines. Existing studies examine one of more specific components, such as science notebooks (Fulton, 2017), curricular coherence (Sikorski & Hammer, 2017), or modeling (Samarapungavan, Bryan, & Wills, 2017). In other studies, FOSS may have been utilized in classroom instruction yet the study focused on another aspect of learning, such as power dynamics (Cochran, Reinsvold, & Hess, 2017). There are also no studies that examine the impact of the NGSS aligned FOSS kits on teachers’ ability to engage students in science.

This chapter will discuss each finding as it relates to current literature, the theoretical framework, and will conclude with a discussion on implications this study has for practice as well as implications for future research.

**Teacher Confidence and Enthusiasm**

The participants in this study indicated an increase in the level of confidence and enthusiasm to teach science as a result of their experience of piloting the FOSS kits. This finding was supported both by the teachers who identified as a “science person” and those that did not. The finding was also supported by teachers who reported feeling confident teaching science prior to using the kits and those that did not. This finding indicates that training, readily available materials, and supportive instructional resources positively impact teachers’ sense of competence
(confidence) and autonomy (enthusiasm). This finding adds to the existing body of literature on teacher confidence (Murphy, Neil, & Beggs, 2007) and enthusiasm (Rosenshine, 1970; Keller, Hoy, Goetz, & Frenzel, 2016). The increased level of teacher confidence and enthusiasm is limited in its contribution to understanding the impact on student engagement as the study did not conclusively reveal how an increase in those levels impacted student engagement, merely that the students were engaged.

Initial and ongoing training were deemed to be essential in embarking upon this new instructional resource. Participants appreciated the opportunity to collaborate with peers, to explore with the materials, and to become familiar with the organization of the instructional resource. Participants reported that the time set aside to become familiar with the resource, rather than trying to learn about it “on the fly” was helpful. This finding is consistent with the available literature on the topic of professional training. Providing elementary teachers with exposure to and experience with content, particularly as it exists in the real world, can provide a sense of comfort in teaching the material (Duncan, Diefes-Dux, & Gentry, 2011). Nadelson et al. (2013) demonstrated the power that hands-on professional development opportunities, similar to those that students will experience, are valuable in increasing teacher confidence and capacity. Similar to the findings of Berlin and White (2012) and Kelly and Staver (2005), participants’ biggest concern was the amount of time and preparation necessary to teach these units and the overwhelming feeling of taking on a new resource. Surprisingly, the majority of participants explicitly indicated that the time was worth it because the students love the activities and the teachers observed a deep level of learning.

Initial and ongoing training can increase teachers’ sense of competence with teaching science and in embracing an autonomy supportive instructional environment. The participants in
the study reported that the hands-on aspect of the instruction was a favorite part for both them and for the students. The noise and mess were deemed critical to the students’ learning experience and several participants advised teachers’ just beginning instruction with the kits to get over the overwhelming feeling because the experience for the students was worth it. Additionally, the participants found value in allowing the students to become more independent in their learning from constructing their own designs, to developing their own focus questions. This is consistent with the tenets of SDT and indications that student engagement and motivation are enhanced in autonomy supportive environments (Niemiec & Ryan, 2009).

The FOSS resource served to increase participants’ content knowledge on the subject matter. Not every participant indicated an increase in content knowledge, however, of those that did they included both teachers that felt confident in their science instruction prior to utilizing the resource and those that did not. Providing teachers with high-quality instructional resources that include a background on the pertinent scientific context can improve content knowledge, and therefore increase their confidence. For some participants, the resource and the accompanying supporting materials made them feel more comfortable teaching a subject with which they are not inherently comfortable. Alternatively, for some, the resources increased confidence in science instruction in that it required less independent research and planning of lessons. This finding is consistent with existing research indicating that elementary teachers are not content area specialists. Capobianco (2010) indicated that since many elementary teachers are not science certified, teaching science or engineering may cause feelings of uncertainty. Poor subject knowledge may lead to negative attitudes about teaching science and, therefore limit teachers’ willingness to provide students with high quality science instruction (Garbett, 2003).
The reported increase in participants’ confidence can be correlated to SDT as an increased sense of competence in their science instruction. Waldrip and Fisher (2001) noted that despite having access to a high-quality science program in their school, teachers’ lack of competence in teaching science led to an avoidance of utilizing the resource. According to Deci and Ryan (1985), competence is an essential nutriment, a basic psychological need. It makes sense that some may avoid the use of a resource that they do not feel competent in utilizing. However, an increased sense of competence may lead to an increased sense of autonomy, thus facilitating intrinsic or internalized extrinsic motivation. Therefore, training that both provides scientific context as well as familiarity with the investigations is necessary to build teacher confidence when implementing a new resource. Additionally, the resource must contain components that increase teacher’s sense of confidence, such as accessible materials and supportive instructional resources.

One of the most difficult aspects of teaching elementary science, as reported by multiple participants, is finding and gathering necessary materials needed to teach high-quality science lessons. This finding is consistent with existing scholarship on the subject (Abd-El-Khalick, Bell, & Lederman, 1998; Tilgner, 1990; Tobin, & Tippett, 2014). Absent of a science program, such as a kit that includes all of the necessary materials, teachers must often purchase materials for science investigations for classroom use. The participants in this study reported access to readily available materials a strength of the resource. Similarly, the participants’ sense of confidence and enthusiasm increased due to the supportive nature of the instructional resources, such as the teacher resource guide, the online components, and the prepared presentation slides. Consistent with the existing literature, the findings of this study support the notion that the lack of available resources can be a deterrence in teaching science at the elementary level.
To summarize, access to materials combined with quality instructional resources and training may have contributed to the increase the participants’ level of content knowledge. Increased content knowledge coupled with readily available materials and supportive instructional resources likely had a positive impact on the participants’ sense of competence (confidence) and autonomy (enthusiasm) in teaching science. The materials and resources increased the participants’ confidence and enthusiasm in both teachers that reported feeling confident in their science ability prior to teaching with this resource and in those that did not. Despite materials and resources being made available to teachers, training in both the effective use of them coupled with training on the conceptual scientific understanding behind the investigations is crucial. Based on the participants' responses, the initial training period is not sufficient in enhancing competence and autonomy. Sustained and on-going professional development must be made available to teachers.

**Student Engagement**

The results of this study indicate that the utilization of the FOSS kits resulted in a high level of student engagement in science. Each of the kits, with the exception of one at the early primary level, was based on either Earth science content or physical science content. Female students tend to be more represented in biological sciences (Blickenstaff, 2005) and therefore, the intention of the pilot focusing on Earth and physical sciences was to provide students with more exposure to high quality science investigations in those areas. Interestingly, only one participant explicitly mentioned female students, the rest of the observations about student engagement with the resource was not differentiated between male and female experience.

Given the gender gap in STEM education at the secondary, post-secondary, and career levels (NCES, 2015; Blickenstaff, 2005), this was a surprising finding. Perhaps if an interview
question specifically addressed the level of participation or engagement by gender, respondents
would have provided insight into the observed differences, or perhaps there were no observable
differences. Miller et al. (2007) found that the interest level in science tends to decline around
middle school, and that the decline is sharper among female students, potentially due to their
lower perception of self as a student of science.

Participants expressed that there was a high level of engagement for all students as a
result of the use of the FOSS kits. In general, participants described student engagement as
observable by the students’ interest and excitement, “on-task” talk in class, and lack of
distractions. These attributes, which were observed as student behavior that resulted in a high
level of student interest and engagement, allowed the theme of optimal challenge to develop. The
optimal challenge resulted in increased dialogue and connections that students made to the real-
world, independent of teacher prompting to do so. The concept of optimal challenge dates back
to the Yerkes-Dodson Law, established in 1908, which correlates cognitive arousal to
performance (Cohen, 2011). This concept has been studied in relation to games (Meng, Pei,
Zheng, & Ma, 2016; Malone, 1980) as well as potential impact on classroom environments
through the lens of self-determination in regard to both intellectual challenge (Guay, Ratelle, &
Chanal, 2008); and in supporting autonomy while providing structure (Jang, Reeve, & Deci,
2010).

The subtheme of optimal challenge, as it relates to student engagement demonstrates how
activities that challenge students at all levels, while allowing for success regardless of students’
particular skill set, supports existing scholarship that educators need to change that notion that
science is only for smart people (Turner & Ireson, 2010). Von Stumm, Hell, and Chamorro-
Premuzic (2011) demonstrated that, while intelligence is the best predictor for academic
achievement, intellectual curiosity and effort can have a significant impact upon and even “rival” intelligence in regard to academic achievement.

The concept of optimal challenge was not directly addressed in the literature review other than in student’s sense of identity being positively impacted when one feels competent in their ability (Carlone and Johnson, 2007). Student engagement in the FOSS activities may be attributed to the challenging, yet attainable design of the activities. Based on participant responses in this study, the level of rigor provided the students with an opportunity to experience success at the fundamental level and the ability for those able to dive deeper to also build their conceptual understanding, thus sustaining engagement and interest regardless of skill level. This finding suggests that providing students optimally challenging learning activities promotes sustained student engagement and interest, both autonomous motivators. Autonomous motivation can lead to positive schooling outcomes such as increased persistence, achievement, challenge-seeking, and creativity (Guay et al., 2008).

Seven of the participants in this study recognized an increase in either students’ engagement with scientific dialogue with peers, talking “on-task” during lessons, or using scientific vocabulary outside of the science classroom setting. These behaviors can be attributed to the explore-first approach to the science content, which helped to develop peer communication skills and a normalized use of the scientific vocabulary. Each of these behaviors can be interpreted as an indication of a sense of competence with the subject matter. This finding is consistent with existing literature that indicates there are social and educational benefits to students’ acquiring acuity in their use of scientific discourse, including an increased sense of scientific identity (Brown 2006; Brown, Reveles, & Kelly, 2005). This finding is relevant because if students in the elementary years can develop an enhanced sense of their scientific
identity, it may lead to more students continuing to be interested in science at the secondary level, thus reducing the trend of declining interest.

A key component of the Next Generation Science Standards (NGSS Lead States, 2013) is a real-world connection of the content to practice. Each of the participants in this study attributed some aspect of the student’s high level of engagement to the real-world connection and application of the activities. One of the subthemes that emerged was the real-world connections that the students made between the learning in class and the world around them. Participants observed phenomena such as; an increased amount of dialogue in class, “on-task” talk in class, an increase in the use of scientific vocabulary, parents commenting on the student discussions about science at home, and students bringing in materials relating to the topic from home. Surprising in the findings was the fact that the students were making real-world connections on their own, without the explicit connection provided to them by the teachers. This finding suggests that because the students were truly interested and engaged in their learning, they independently sought out connections to the world around them without prompting, an example of autonomous behavior.

To summarize the findings on student engagement, the concept of a gender gap was absent from participant responses in the study. The FOSS kits provided students with an optimal challenge, thus resulting in sustained student engagement and interest in the science content. The hands-on component of the kits is founded on an “explore-first” approach which helped build conceptual understanding, thus increasing students’ sense of competence with the subject matter. The increased sense of competence may be a contributing factor to the sustained level of interest and engagement observed as a result of the optimal challenge. Autonomous behaviors were also observed via the real-world connections that students self-initiated.
Hands-On Learning

The hands-on component of the FOSS kits is a foundational premise to this science resource. The participants reported an appreciation for the hands-on component because the students enjoyed it and it led to a deep understanding of the content. Participants described the hands-on component of the instruction as intrinsically engaging in that they did not have to try to engage the students in the learning, the engagement and interest was organically derived by the students. Additionally, the participants stated that the hands-on aspect of the science instruction was embraced by the students because it allowed them to take ownership of their own learning. They were able to explore and figure things out without being told the facts, such as in a traditional style of instruction. Similar to existing literature, findings on kit-based science instruction as reported by the participants in this study are consistent with the positive impact on student attitudes toward science (Kelly & Staver, 2005; Houston et al., 2008) and an overall satisfaction with the classroom environment (Houston et al., 2008).

Participants in this study correlated the “explore first” subtheme to helping students develop conceptual understanding of the concept prior to introducing the scientific ideas. The notion of the necessity to develop conceptual understanding was reflected as a central ideology in the NGSS as a way to produce meaningful learning experiences. This approach is also referred to as a context based approach. De Putter-Smits, Taconis, Jochems, and Van Driel (2012) conducted a study that indicated teachers with more experience in the context based approach have a greater sense of competence in teaching in that manner. The participants in this study reported similar findings in that the students took ownership of their learning and developed a deep understanding of the content. Additionally, the participants felt more competent in
delivering the instruction because they had readily available materials to provide the students and supportive instructional resources to assist in the instructional delivery.

Student engagement during the hands-on portion of the science instruction was described by the participants in a manner consistent with self-determined behaviors. In other words, the students were participating and engaging with the materials out of their own curiosity and for the sake of their own enjoyment, not because they were told to do so. However, it is unreasonable to assume that all students were engaged because they were intrinsically motivated. As described by Ryan and Deci (2000a), the most internalized form of extrinsic motivation is integrated regulation and while extrinsically motivated behaviors initially need external prompting, they may result in one finding the activity intrinsically motivating. This finding is consistent with literature describing classrooms that support students’ needs for autonomy, competence, and relatedness result in students that tend to be more intrinsically motivated (Niemiec & Ryan, 2009).

Recent work by Vansteenkiste et al. (2017) suggests that strategies such as providing students with rationales for the learning may allow them to see the self-relevance and therefore internalize the value of the learning. Early exposure to science is important in engaging students in science, before they have time to allow misconceptions about ability to influence their motivation to pursue interest in the field. Once academic intrinsic motivation is established for a particular subject area, it may not be easy to change and it becomes increasingly more difficult to change through adolescence (Gottfried, Fleming, & Gottfried, 2001). The FOSS kits are designed to incorporate real-world connections and appear to elicit positive motivational tendencies. This finding suggests that teachers can benefit from training to support strategies that
promote self-determined behaviors in the classroom, particularly when a learning activity or subject is not inherently interesting to the students.

Participants indicated that the structure of the hands-on aspect of the FOSS kits enabled all learners to experience challenging yet attainable instruction. Students that struggle with the spoken and written aspects of schooling were able to find success with the hands-on activities. Participants indicated that the students were engaged in the activities and were able to find success with some component of the lesson, typically the hands-on piece. Participants also reported not needing to facilitate participation as the students were excited to use the materials.

Based on the participants’ descriptions of the students’ active involvement, it can be concluded that the students appear to have been motivated by autonomous, rather than controlled behaviors, such as the teacher persuading the students to participate. This finding suggests that the hands-on aspect of the FOSS resource facilitates certain aspects of an autonomy supportive classroom environment. Although, it should be noted that teachers must receive training in strategies aimed at creating more autonomy supportive environments. Ryan and Deci (2017) state that “school climates that support autonomy foster more self-motivation, persistence, and quality of learning. Structure, as a scaffolding and support for competence, is shown in many SDT studies to complement autonomy support.”

The hands-on, explore first approach, which challenges students at their level, precipitates an autonomy supportive classroom environment in which the teacher is able to promote students’ ownership of their learning. The structure of the activities is scaffolded in a way to allow all students to find success and provide opportunities for those able to go deeper to do so, thus increasing the sense of competence in the students. Interestingly, this approach also seemed to increase the competence of the teachers as they were provided with the materials and
resources to feel knowledgeable on the topic, and some felt comfortable learning alongside the students even if they did not have the answers.

The benefits of instructional integration were mentioned by several participants, particularly in regard to the student journals and the amount of reading and writing the students did over the course of an investigation. The hands-on aspect of the instructional resource was reported to lend itself to students’ recording findings and inquiries. Similar to scholarship in the existing literature, teachers can maximize valuable instructional time by integrating content areas, such as science and English Language Arts (NRC, 2014; Johnson et al., 2015). Participant responses about the lack of time for science, coupled with the need to dip into other instructional areas, supported existing literature about the challenges of implementing an integrated curriculum (Berlin & White, 2012; Carrier et al., 2013).

The findings of this study support existing literature on kit-based programming in that they have shown to have a positive impact on student attitudes toward science (Kelly & Staver, 2005; Houston et al., 2008) and provide teachers with tools to enhance science learning (Robardey et al., 1994; Slavin et al., 2014). The limitations of this study do not allow for findings to support existing literature on the positive impact on student achievement (Young & Lee, 2005; Dickerson et al., 2006) because there was no required assessment component to the pilot and the participants did not generally speak to measured academic performance. However, most participants did indicate a formative measure of a deeper level of student understanding based on their observations. This finding suggests that while the use of the FOSS resource had a positive impact on student attitudes toward science, as gauged by their level of engagement, and while they provided teachers with tools to enhance their instruction, it is unclear about the impact on student performance as it was not measured in this study.
To capture the findings on the superordinate theme of hands-on learning, the approach was found to be naturally engaging, meaning that the teachers did not have to employ strategies to increase student engagement. The hands-on aspect of the FOSS kits allowed students to take ownership over their learning and they were reported to participate out of their own curiosity and enjoyment for the learning activities, not due to expectations of coercion, thus autonomous behavior. The challenging yet attainable content served to produce conceptual understanding of the scientific concepts while fostering autonomy and an increased sense of competence as students with a wide range of skills were able to find success. The findings indicate that teachers would benefit from strategies to promote self-determined behaviors in the classroom and to promote autonomy supportive classroom environments.

**Implications for Practice**

The positive response to the implementation of the FOSS kits correlated to an increased sense of confidence and enthusiasm for teaching science. When implementing any new elementary science kit-based resource, districts should strive to build teacher capacity through initial and ongoing training which provides scientific context as well as familiarity with the investigations. This training is necessary to build teacher confidence and a level of comfort with the implementation of a new resource. Additionally, since the readily accessible materials, coupled with supportive instructional resources, played a large role in the increased sense of confidence, districts should strive to replicate features of these components in any hands-on resource that is adopted.

Providing students hands-on learning experiences increases student motivation and engagement (Niemiec & Ryan, 2009; Reeve et al., 2004; Pelletier et al., 2002). Elementary teachers would benefit from training aimed at equipping teachers with techniques to relinquish
autonomy controlling tendencies for more autonomy supportive strategies in order to increase student motivation and engagement. This is true in science, but may also benefit students across all instructional areas.

Hands-on learning provides students the opportunity to explore with materials, can be designed to challenge them at a developmentally appropriate level, and may result in a deeper understanding of the content. As noted by participants in this study, having the necessary materials readily available is desirable, as long as they are not overwhelmed by the sheer volume of materials. Districts must maintain a kit-based resource by replacing the consumable materials and maintaining the quality of the equipment. The initial cost of purchasing a kit-based program can be steep, yet the district must also plan for the maintenance of the kits and training of new teachers throughout the duration of the implementation. Existing literature (Young & Lee, 2005) demonstrates the struggle of sustaining a kit-based program as they can be difficult to maintain due to the necessary allocation of funding for training and resource management. It is imperative that a district seeking to implement a kit-based program have a short and long term plan for funding the initial purchase of the resource, the initial training, the ongoing training, and the maintenance of the resource.

The findings of this study will impact practice in the following ways:

- Districts must work to build elementary teacher capacity in both scientific context and inquiry-based, autonomy supportive pedagogy in order to increase teacher competence in science instruction and students’ competence and autonomy with science. The researcher will work directly with the K-5 teachers in the district as the rollout of FOSS expands to full implementation. Teachers will receive initial training and the opportunity for ongoing training on both context-based and pedagogical aspects of effective elementary science
instruction will be offered. The researcher will plan and deliver professional development opportunities on best practice pedagogical science instructional delivery methods aligned to the New York State Science Learning Standards (NYSSLS). Curricular revisions needed to align to the NYSSLS will involve as many classroom teachers as possible in order to build capacity and deepen content knowledge.

- Students benefit from challenging, yet attainable, academic challenge. It is imperative that elementary science not become stand-alone, hands-on activities but that they are integrated into a thoughtful curriculum that provides students opportunity to develop meaningful connections to the real-world in a vertically aligned progression of concepts. The researcher will propose a plan to the district that incorporates the inclusion of one FOSS kit per grade level and two supplemental units, likely a combination of BOCES kits and in-house developed kits, to accommodate the remaining two disciplines at each grade level. The plan will provide vertical alignment to ensure that the student’s experience a progression that builds conceptual understanding through their elementary years and into middle school. The thoughtful development of units to address each of the three disciplines; physical science, life science, and Earth and space science, will provide teachers with comprehensive units of instruction that align to the state standards and will prevent the need to find activities that promote isolated learning experiences.

- High-quality, hands-on science can benefit both teachers and students. The primary concern from participants was the amount of time required for planning and teaching the lessons. Districts must commit to increasing the amount of instructional time dedicated to elementary science. The Fairport Central School District committed last year to the inclusion of a minimum of 30 minutes of science or social studies per day at each
elementary building. This time is not necessarily indicated on the master schedule but a caveat for the teachers to uphold. The researcher will continue this conversation with district office and building leadership to advocate for more freedom in the teacher’s schedules to accommodate the time required to teach high-quality, hands-on science instruction. The positive feedback about the benefits of hands-on science instruction from the participants of this study and the repeated concerns about the lack of time will serve as the foundation for the advocacy.

- Based on the positive responses from the participants, the researcher will submit a textbook adoption request to the district to formally adopt FOSS as the primary resource for the discipline in which it is being piloted at each grade level. This means that each grade, Kindergarten through fifth, will have one FOSS kit that addresses either Earth science or physical science. Due to the length of time required to teach each kit and the limited amount of instructional time in the school day, the district will need an alternate plan to address the other two disciplines at each grade level Alternatives may include a district-developed or regionally developed resource. Imperative in the rollout of the new curriculum aligned to the new standards is a short and long term professional development plan. The researcher will work with the Director of Professional Development and district office to outline a feasible schedule for teacher release time for teachers new to FOSS, as well as for the rollout of newly developed resources in addition to FOSS to equip teachers with the contextual background and pedagogical method for instructional delivery of hands-on science. The plan will consist of a five year vision for integrating the new resources aligned with high-quality and meaningful training.
• The district has started an initial professional development partnership with Dr. Christopher Niemiec to provide teachers with an overview of Self-Determination Theory and how it can be applied to the classroom setting. Thus far, the sessions have provided interested teachers with an overview of SDT. The second phase will include more practical application of SDT in the classroom environment targeted at interventions effective for specific grade bands by bringing small groups of teachers together to discuss effective strategies. The third phase would include classroom observation and more targeted interventions. The researcher will work with the district to expand this partnership to build teacher capacity for developing autonomy supportive behaviors and autonomy supportive classroom environments.

• The researcher will provide the district with an estimated cost for equipping each grade level with enough kits to teach the adopted FOSS units. This may require a multi-year adoption. The researcher will coordinate with the local BOCES to develop a contract to refurbish the kits yearly to ensure that the materials are properly maintained and replenished as needed. This process has already begun on a small scale, however there are logistics to consider for equipping the high volume of teachers in the district.

• District-developed resources or regionally developed resources must include components that attributed to the success of the FOSS kits, such as the background information for the teacher and the prepared presentation materials. The cost for developing such supplemental resources will be calculated by the researcher, along with a projected timeline, and proposed to the district for inclusion into the curriculum writing budget.

**Implications for Future Research**
The participants in this study voluntarily offered to share their experience with teaching the FOSS kits. Therefore, it is difficult to determine whether the results are typical for all teachers piloting the FOSS kits or if the reported positive experience resulted from the fact that participants volunteered because they had a positive experience. The pilot is in the third year and all teachers currently using the resource are doing so voluntarily. However, future research could assess teacher confidence and enthusiasm, student engagement, and the perceptions of hands-on learning among all teachers utilizing the kits, not just those that volunteered for the study. Additionally, once the kits are adopted and fully implemented by all teachers in the district, without choice in piloting, a follow up study to determine teacher perceptions would be valuable in learning how to support those that may not feel comfortable with the resource.

Given that only one participant, who taught an upper intermediate grade level, differentiated between female and male students, it is worth exploring why female interest and engagement in science tends to diminish as students get older. This study consisted of participants that taught in grades Kindergarten through fifth. Future research that examines whether or not there are differences in students’ competence, autonomy, or relatedness in regard to participation and engagement with the FOSS kits at the elementary level would be valuable in understanding if there is generally a point where noticeable differences in participation, engagement, and interest are observed. Additionally, examining whether the implementation of a resource such as FOSS, starting in the early elementary years, has an impact on student perceptions of self as a student of science later in their educational career would be valuable for the field.

Interestingly, of the forty five participants recruited for the study, six were male, 13%. Of the nine participants, 3 were male, 33%. Each of the three male participants, 100%, identified as
a “science person” whereas three of the six female participants, 33%, identified as a “science person.” There is an opportunity for future research to explore if one’s identity with and competence in science correlates with their willingness to teach science, and if gender plays a role. Another potential area of future research is to examine whether the gender gap in STEM, as supported by existing literature, is perpetuated by elementary teachers that feel uncomfortable in teaching science.

This study revealed that the elementary students were engaged and interested in the science, some participants indicated that the students would do science all day if they could. A longitudinal study on the impact of early exposure to science on student’s science identity in order to determine the causal relationship of early exposure to science and interest in science at the secondary level would be valuable to the field.

The findings of this study support future research to answer the following considerations:

- The correlation between early exposure to high-quality, hands-on science and the impact on student perceptions of self as a student of science as they get older.
- Teachers’ use of autonomy supportive strategies versus autonomy controlling and the impact on students’ perceptions of competence with science and views of self as a student of science.
- Student gender identity and the correlation to their confidence in approaching science at the elementary and secondary levels.
- Teacher confidence in science instruction and the relationship to time spent teaching science.
- The relationship between teachers’ gender and their confidence in teaching science as well as the impact on students of both genders.
- Locally, an examination to determine whether FOSS pilot teachers not included in this study exhibit similar positive experiences with the FOSS kits and their impact on teacher confidence, student engagement, and the benefits of hands-on learning.

- Once adopted and fully implemented, examine teacher perceptions of the FOSS kit, particularly those resistant to try it, and how to best support teacher’s sense of competence.

**Conclusion**

This study was prompted by the problem of practice: the minimal amount of instructional time and attention allocated to science, coupled with the lack of adequate resources and formal science training, result in a missed opportunity to engage elementary students in science. The study was guided by the research question: How do teachers describe their understanding of the impact of FOSS on their ability to engage students in science? Findings from this study indicate that the hands-on nature of the science learning activities, as supported by quality materials and supportive instructional resources, led to sustained student engagement in science and increased teachers’ confidence and enthusiasm in teaching science. The findings did not necessarily support an increase in teachers’ ability to engage students in science, rather, the hands-on and optimally challenging nature of the kits sustained a high level of student engagement without active strategies employed by the participants.

Educators must make an effort to provide rationale to learning activities in an effort to enhance self-relevance and therefore increase self-determined behaviors in students. Students that engage in activities out of curiosity and enjoyment are likely more intrinsically motivated. Training can be provided to educators on strategies to increase extrinsic motivation in an attempt to achieve internalization of those learning behaviors. While the participants in this study
indicated a high level of student motivation to participate in the learning activities, there are several factors that may have contributed to that finding. For example, the participants are part of a pilot with no expectation to teach the kit in its entirety. The novelty of a new resource may have been a contributing factor of student engagement as not every teacher in every grade is utilizing a FOSS kit. Perhaps the science activities will continue to engage students at the high level described by participants in this study, however, strategies to increase student’s desire to engage with academic experiences may increase their effort and curiosity. Increased effort and curiosity can have a positive impact on academic performance (Meece, Blumenfeld, & Hoyle, 1988; Linnenbrink, & Pintrich, 2002; Von Stumm et al., 2011).

Elementary teachers are not content expert teachers and districts often fail to provide elementary teachers with adequate instructional resources and training to effectively teach high-quality science. The results of this study indicate that the FOSS kits provided students with a high-quality, hands-on science experience that that led to sustained student engagement and increased teacher confidence and enthusiasm. The limitations of this study do not allow for making a determination on whether the student engagement in the elementary setting will result in increased engagement through a student’s secondary educational career, however that would make for a valuable longitudinal study in the future.

The results of this study provide useful information for instructional practice and future research. While the upfront cost of FOSS may make it unrealistic option for a full district implementation of all science disciplines, local and regional districts can strive to incorporate successful components of the FOSS kits, such as the explore-first approach coupled with supportive instructional resources that are challenging yet attainable, into newly developed curricular resources. Regardless of the resource, whether a kit option or an internally developed
one, initial and ongoing training is necessary to facilitate teacher competence with the subject matter and instructional delivery. Consistent with existing scholarship on the subject, the most negative aspect of the FOSS kits was the amount of time and preparation required to plan and teach the lessons. Unless districts are willing to allocate more time for science instruction in the school day, it does not matter how beneficial a resource may be for teachers and students, the result will continue to be the same; a missed opportunity to engage elementary students in science.
References


http://doi.org/10.1111/ssm.12061


Reeve, J. (2009). Why teachers adopt a controlling motivating style toward students and how they can become more autonomy supportive. Educational Psychologist, 44(3), 159-175.

Reiners, G. M. (2012). Understanding the differences between Husserl’s (descriptive) and Heidegger’s (interpretive) phenomenological research. Journal of Nursing Care, 1(5), 1-3.


http://doi.org/10.1016/j.sbspro.2012.09.651
Appendix A - Phase One Recruitment Email

Dear Prospective Participant:

As you may know, I am nearing the completion of my Doctor of Education program in Curriculum, Teaching, Learning and Leadership through Northeastern University. I am currently working on my dissertation and am writing to invite you to participate in a research study aimed at seeking to understand how you, as a K-5 teacher involved in the Full Option Science System (FOSS) pilot, describe your understanding of the impact of FOSS on your ability to engage elementary students in science.

You have been selected as a potential participant because you have been involved in the FOSS pilot for at least one year prior to this school year. The minimum expectation is that you have taught at least one FOSS investigation. Should you choose to participate in this study, we would meet for approximately one hour, although we will schedule 90 minutes just in case the discussion runs long, to talk about your experiences with FOSS. The one-on-one interview will take place sometime between December and February at a time and place most convenient for you. The interview will be audio recorded and later transcribed.

Should you choose to participate in the study, your identity and responses will remain confidential; every participant will receive a pseudonym which will be used for all references to the interview. Your responses, both positive and negative, will be valuable to the research and to the district. Your participation is completely voluntary and you may choose to withdraw from the study at any time, for any reason, even after it has begun should you choose to do so.

I hope to interview 12 participants in grades K-5. If you are interested in participating in this study or if you have questions, please email me at my Northeastern University email address, larsen.k@husky.neu.edu within 10 days to inform me of your interest. Depending on the number of responses 10 days from today, I will inform you of the selection decision. Should you choose not to participate, I thank you for your time.

Sincerely,

Kristin Larsen

EdD Candidate, Northeastern University
Appendix B- Phase Two Recruitment Email (if necessary)

Dear Prospective Participant:

As you may know, I am nearing the completion of my Doctor of Education program in Curriculum, Teaching, Learning and Leadership through Northeastern University. I am currently working on my dissertation and am writing to invite you to participate in a research study aimed at seeking to understand how you, as a K-5 teacher involved in the Full Option Science System (FOSS) pilot, describe your understanding of the impact of FOSS on your ability to engage elementary students in science.

You have been selected as a potential participant because you are involved in the FOSS pilot. Knowing that this is the first year that you have participated in FOSS, the minimum expectation is that you have taught at least one FOSS investigation. Should you choose to participate in this study, we would meet for approximately one hour, although we will schedule 90 minutes just in case the discussion runs long, to talk about your experiences with FOSS. The one-on-one interview will take place sometime between December and February at a time and place most convenient for you. The interview will be audio recorded and later transcribed.

Should you choose to participate in the study, your identity and responses will remain confidential; every participant will receive a pseudonym which will be used for all references to the interview. Your responses, both positive and negative, will be valuable to the research and to the district. Your participation is completely voluntary and you may choose to withdraw from the study at any time, for any reason, even after it has begun should you choose to do so.

I hope to interview 12 participants in grades K-5. If you are interested in participating in this study or if you have questions, please email me at my Northeastern University email address, larsen.k@husky.neu.edu within 10 days to inform me of your interest. Depending on the number of responses 10 days from today, I will inform you of the selection decision. Should you choose not to participate, I thank you for your time.

Sincerely,

Kristin Larsen
EdD Candidate, Northeastern University
Appendix C- Letter of Acceptance Template

Dear (insert name):

Thank you for responding with interest to participate in my dissertation research study, Understanding the Impact of a Kit-Based Science Resource on Teachers’ Ability to Engage Students in Science: An Interpretative Phenomenological Analysis. I am happy to inform you of your acceptance into the study. The next step is to schedule our interview. I anticipate this to take approximately one hour, however we will schedule 90 minutes just in case the discussion runs long. When we meet I will provide you with an informed consent form to sign. Again, you may choose to withdraw from the study at any time, for any reason, should you choose to do so.

After our interview, I will send your audio recording to a confidential, third party service for transcription. Once I receive it in typed format I will send it to you to review for accuracy. The only face-to-face time commitment required of you is the initial interview.

Can you provide me with dates and times that are convenient for you as well as a location that is comfortable for you so that we may schedule our interview?

Thank you,

Kristin Larsen
EdD Candidate, Northeastern University
Appendix D- Letter of Rejection to Study

Dear (insert name):

Thank you for responding with interest to participate in my dissertation research study. I regret to inform you that I have reached the desired number of participants in the study and will not require your participation. I truly appreciate your willingness to assist me in the completion of my dissertation and am sorry that I will not have the opportunity to hear your in-depth experiences with FOSS and how it impacted your ability to engage elementary students in science as part of this study. Please feel free to email me with any questions or concerns.

Sincerely,

Kristin Larsen
EdD Candidate, Northeastern University
Appendix E- Informed Consent Document

Northeastern University, College of Professional Studies

Name of Investigators: Kimberly Nolan (Principal Investigator) Kristin Larsen (Student Researcher)

Title of Project: Understanding the Impact of a Kit-Based Science Resource on Teachers’ Ability to Engage Students in Science: An Interpretative Phenomenological Analysis

Informed Consent to Participate in a Research Study

We are inviting you to take part in a research study. This form will tell you about the study, but the researcher will explain it to you first. You may ask this person any questions that you have. When you are ready to make a decision, you may tell the researcher if you want to participate or not. You do not have to participate if you do not want to. If you decide to participate, the researcher will ask you to sign this statement and will give you a copy to keep.

Why am I being asked to take part in this research study?

You are being asked to take part in this study because you are a Kindergarten through fifth grade teacher piloting the Full Option Science System (FOSS) kits in the Fairport Central School District.

Why is this research study being done?

The purpose of this study is to better understand teachers’ perceptions with the experience of teaching FOSS and the impact FOSS has on their ability to engage students in science. Knowledge generated from the study will serve to inform instructional decision making in the district to foster teacher competency and student engagement.

What will I be asked to do?

If you decide to take part in this study, we will ask you to participate in one face-to-face interview for about 60 minutes, although a 90 minute block of time will be scheduled in case the discussion runs long. Once the interview is transcribed, we will ask you to review the text via email to confirm that it is an accurate representation of your responses. You will be given the opportunity to approve, make any corrections, or clarify any confusion that you notice.

Where will this take place and how much of my time will it take?

The interview will take place at a location of your choice, and a time that is convenient for you. The interview will take about an hour. You will receive a copy of the transcript as soon as it is available; the follow-up approval of the transcript will take as long as it takes you to read the transcription. You are not required to provide comments if you feel that the transcript is an accurate representation of your responses.

Will there be any risk or discomfort to me?

...
Risks to participating in this study are minimal and unlikely. Participants may feel uncomfortable sharing their personal stories related to their experiences. Participation in the study in no way impacts participation in the pilot.

**Will I benefit by being in this research?**

There will be no direct benefit to you for taking part in this study. However, the information learned from this process may help you reflect upon your instructional delivery of the FOSS material.

**Who will see the information about me?**

Your participation in this study will be confidential. Only the researchers on this study will see the information about you. No report publications will use information that can identify you in any way or any individual as being part of this project. You will be assigned a pseudonym and a number which will be used throughout the study as opposed to your real name. Audio files and transcripts will be kept on a password protected person computer of the student researcher throughout the duration of the study and will be destroyed at the completion of the study.

**What will happen if I suffer any harm from this research?**

No special arrangements will be made for compensation or for payment for treatment solely because of my participation in this research.

**Can I stop my participation in this study?**

Your participation in this research is completely voluntary. You do not have to participate if you do not want to and you can refuse to answer any question. Even if you begin the study, you may quit at any time. If you do not participate or if you decide to quit, you will not lose any rights, benefits, or services that you would otherwise have as a FOSS pilot teacher and employee in the district.

**Who can I contact if I have questions or problems?**

Include the name and viable contact information of one or more appropriate people. If there is a possibility of an emergency, be sure an immediate response is available. Ex: If you have any questions about this study, please feel free to contact the person primarily responsible for the research, Kristin Larsen at larsen.k@husky.neu.edu or on her cell at (585) 224-5887. You can also contact the Principal Investigator and faculty member at Northeastern University at K.Nolan@northeastern.edu.

**Who can I contact about my rights as a participant?**

If you have any questions about your rights in this research, you may contact Nan C. Regina, Director, Human Subject Research Protection, Mail Stop: 560-177, 360 Huntington Avenue, Northeastern University, Boston, MA 02115. Tel: 617.373.4588, Email: n.regina@neu.edu. You may call anonymously if you wish.

**Will I be paid for my participation?**

You will not be paid for your participation in this study.
Will it cost me anything to participate?

It will not cost you anything to participate in this study.

Is there anything else I need to know?

N/A

I agree to take part in this research.

_________________________________________________________________________  ________________________
Signature of person agreeing to take part  Date

_________________________________________________________________________
Printed name of person above

_________________________________________________________________________  ________________________
Signature of person who explained the study to the participant above and obtained consent  Date

_________________________________________________________________________
Printed name of person above
Appendix F- Semi-Structured Interview Protocol

**TOPIC:** Understanding the Impact of a Kit-Based Science Resource on Teachers’ Ability to Engage Students in Science: An Interpretative Phenomenological Analysis

Institution: Northeastern University
Interviewee (pseudonym and number):
Interviewer: Kristin Larsen
Date of interview:
Time of interview:
Location of interview:

**PURPOSE:** The purpose of this study is to better understand teachers’ perceptions with the experience of teaching FOSS and the impact FOSS has on their ability to engage students in science. Knowledge generated from the study will serve to inform instructional decision making in the district to foster teacher competency and student engagement.

**RESEARCH QUESTION:** How do teachers describe their understanding of the impact of FOSS on their ability to engage students in science?

Today we will be talking about how you, as a teacher piloting FOSS, describe your understanding of the impact FOSS has on your confidence in teaching science as well as student engagement in science. You will be assigned a pseudonym and a number and your identity will remain confidential. This interview should take about an hour.

Introductory Protocol: Thank you for agreeing to meet with me today and have a conversation about your experience with teaching FOSS. Because your responses are important and I want to make sure to capture everything you say, I would like to audio tape our conversation today. You have previously provided permission for me to record you, however do I formally have your permission to record this interview? (WAIT for response) Thank you, I really appreciate your participation in this research, it will be valuable to both my dissertation and to help inform the district. I will also be taking written notes of our conversation. I can assure you that all responses will be confidential and only a pseudonym will be used when quoting from the transcripts. I will be the only person privy to the audio recordings and transcripts, which will be destroyed at the conclusion of this project.

You have been selected to speak with me today because, as a teacher who has used the FOSS kits in your instruction, you have a great deal to offer about your perceptions of how they impact your ability to engage students in science.

This interview should last about an hour. I have several questions that I would like to ask during that time, but hope that you will feel comfortable to elaborate as much as possible, draw from your experiences, and provide stories about your experiences. This will allow me to draw better conclusions in the end. You may refuse to answer any question if you choose to do so and you may end your participation in the project at any time should you choose to. Does this protocol sound acceptable to you? Do you have any questions for me before we begin?
INFORMED CONSENT: Describe and have participant sign if interested in continuing.

Start recording

Interview Part I: Interviewee Background (5-10 minutes)

A. Interviewee Background

1) Okay, let’s get started. Can you start by telling me, what is your current position?

2) How long have you been involved in the FOSS pilot?

3) Is science and/or engineering a subject that you are interested in personally, outside of your professional role? In what way?

4) What is your favorite part of teaching science?
   Follow up- And your least favorite part?

Interview Part II:

1) Can you describe for me your experience of teaching science with the FOSS kit being piloted at your grade level?
   Potential follow ups:
   a) What are some pros and cons of the resource?
   b) What are your thoughts on the depth of science content?
   c) What are your thoughts on the materials for student use?
   d) What are your favorite/least favorite parts of the kits?
   e) What are the students favorite and least favorite parts of the kits?
   f) Can you describe how the materials in the kits challenge students and how they allow for success?

2) Based on your experience with FOSS, do you see the kits having an impact on how students engage with science?
   Potential follow ups:
   a) How do you know that they are engaged?
   b) How is the level of engagement different from what you have seen with other resources?
   c) Can you describe a situation in which you observed the students engaged while using FOSS?
   d) Do you feel that students’ sense of competence in science was impacted by the use of this resource? In what way?
3) Can you talk to me a bit about your confidence in teaching science both before and after the experience of using the FOSS kits?
   Potential follow ups:
   a) In general, do you typically feel competent in delivering science instruction? Does FOSS play a role?
   b) In general, do you typically feel competent in your science content area knowledge at your grade level? Does FOSS play a role?
   c) Can you describe a situation where you noticed a change in your level of confidence?

4) Can you describe how FOSS has impacted your ability to engage students in science?
   a) What are some strategies you typically use to engage students in science?
   b) Have you learned new strategies to engage students in science?
   c) Do students seem equally engaged in science as they did with other resources?
   d) Based on your experience, what do you think contributes to student engagement in science?

5) Can you describe the level of training you received with FOSS? What else would have been helpful?
   a) Is there something that could still be helpful to more successfully implement FOSS into your classroom?

6) What advice do you have for teachers that will be starting FOSS in the future?

7) Do you have anything that you want to add that we may not have discussed or anything that you want to add to a previous response?

Stop recording

Thank you so much for your time today. I will have this interview transcribed and you can expect an email from me with the transcript attached for your review.
Appendix G - Transcript Review Template

Dear (insert name),

Thank you again for your time on (insert date) and for your willingness to assist in my research project. I learned a great deal from your experience and the information that you provided will not only help in completing my dissertation, but will inform instructional decision making for the district. As we discussed, I am sending you this follow up email with the transcription of your interview attached. Please take a look at it and reply to let me know if you feel that it accurately reflects the information that you intended to share. You have the opportunity to make corrections, clarify any confusion, elaborate upon a point, or add any thoughts that you had since the interview. Please do so in writing on this document, attach it, and reply to this email.

Should you choose to make edits, please send the document back to me within 15 days, or by (insert date). If you have nothing to change, please send me a quick email to let me know.

Thank you again for your time,

Kristin Larsen
EdD Candidate
Northeastern University
Larsen.k@husky.neu.edu