The Effects of the Next Generation Science Standards (NGSS) on Teaching Practices: An Instrumental Case Study

A Doctoral Thesis Presented to
School of Education
College of Professional Studies
Northeastern University

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Education

by
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August 2018

Abstract

Research shows that U.S. students continue to lag behind in science and mathematics internationally (Fleischman, Hopstock, Pelczar, & Shelley, 2010; Provasnik et al., 2012). A recent study found there is a direct link between students' mastery of academic subjects and their ability to collaboratively problem solve, a critical 21st century skill (OECD, 2016). Unless U.S. schools explicitly teach collaborative problem solving, U.S. students will be insufficiently prepared to adapt to the ever-changing demands of the future. The recently developed Next Generation Science Standards (NGSS) represent a significant departure from past approaches to science education, which has implications for classroom teaching and student learning (Bybee, 2014). This study found that with the support of an NGSS-aligned curriculum, effective district and building-level professional development, and the formation and support of a district-level teacher leader network and school-level professional learning communities, teachers reported altering their teaching practices by releasing responsibility, differentiating instructional approaches, and adjusting their assessment of student capacity. This study additionally revealed that these changes in practices resulted in increased collaboration, mastery of science concepts, and engagement and participation; improved academic vocabulary and discourse; and improved student behavior in the science classroom. Finally, this study found that participating teachers shifted their beliefs around teaching and learning, recognizing science has strong connections with other core subjects; student collaboration can greatly impact learning outcomes; responsibility for learning should be shared with students; and student demographics should not dictate teacher expectations.

Keywords: 21st century skills, KnowAtom ™, learning outcomes, Next Generation Science Standards, standards-based reform

Acknowledgements

First and foremost, I would like to thank God Almighty for giving me the strength, knowledge, courage, and opportunity to undertake this research study and to persevere until its completion. Without His blessings, this achievement would not have been possible.

Dr. Al McCready, my dissertation chair, thank you for your guidance throughout my doctoral study and related research. Even with all the changes that occurred during the process, you were adaptable and provided your wisdom and time to mentor me until I had reached my goal.

Dr. Margaret Gorman and Dr. Jennifer Walsh-Rurak, my committee members, thank you for your insightful comments and encouragement throughout this journey. Your comments were useful and helped me produce a stronger finished product.

Dr. Sue Henderson, I appreciate the time you spent peer reviewing my paper and offering suggestions to improve the paper's flow. Your recommendation to state "just the facts" helped minimize my own bias and subjectivity.

My friends and family, who are literally spread all over the globe, thank you for believing in me and offering me support in the form of laughter, motivation, and distractions when necessary. I especially appreciate my children for being patient with me as I was juggling the roles of being a mother and teacher while being in school full time.

My study participants, thank you for the time you gave, especially knowing it was the busy period at the end of the school year. I appreciate the confidence you placed in me to share your stories and your teaching experiences.

My students, thank you for making me feel like anything is possible. Although you called me teacher, I was the one learning alongside you. I was consistently motivated by seeing your curiosity and determination to keep asking questions.

Buster Waters, my husband and dearest friend, it is to you this work is dedicated. You have been my strongest advocate and support. You inspired me to finish the bachelor's degree I had started before life happened. While living in Costa Rica, you saw the passion I had for teaching, and you pushed me to keep growing and to earn my master's degree in education. You believed in me and made me believe in myself. Throughout this long journey toward earning my doctorate, you have been a constant source of strength and encouragement. Regardless of how many times I read my paper to you or vented my frustration over not finding the words to express what I wanted to say, you listened attentively and offered reassurance. Even after all of our years together, you still bring me flowers, paint me pictures, write me poetry, and rub my feet after a long day. You make me feel so loved and I am truly grateful for the blessing of walking through life holding your hand.

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The Effects of the Next Generation Science Standards on Teaching Practices

Chapter One: Introduction

Background

With the passage of "No Child Left Behind" (NCLB) in 2002, which required every U.S. K-12 student to become "proficient" in reading and mathematics by 2014, each of the states began to increase its focus on reading and mathematics (CEP, 2006). However, each state was given the task of establishing its own set of standards and developing its own set of standardized tests to accomplish the national goal if it was to receive federal education grants (Stansfield, 2011, p. 389). On a national scale, it was difficult to compare results between states because the standards varied greatly from state to state (Cronin, Kingsbury, Dahlin, & Adkins, 2007). However, on an international scale, it was clear U.S. students were falling behind in science (OECD, 2003).

In 2008, the National Governors Association (NGA) and the Council of Chief State School Officers (CCSSO) recommended that states "upgrade state standards by adopting a common core of internationally benchmarked standards in mathematics and English language arts (ELA)/literacy for grades K-12 to ensure that students are equipped with the necessary knowledge and skills to be globally competitive" (National Governors' Association, 2008, p. 6) By 2009, forty-eight states, two territories, and the District of Columbia began developing a set of common standards. The states were guided by the best standards already in existence, as well as feedback from experienced teachers, content experts, and the general public. By June of 2010, the NGA and CCSSO released the final Common Core State Standards (CCSS) and, by 2013, the CCSS in ELA/literacy and mathematics had been adopted by forty-five states, the Department of

Defense Education Activity, the District of Columbia, Guam, the Northern Mariana Islands, and the U.S. Virgin Islands.

NCLB's augmented focus on raising test scores, especially in reading and mathematics (Sunderman, Kim, & Orfield, 2005), had a ripple effect for other subjects. Linn (2003) explains, "It is no surprise that attaching high stakes to test results in an accountability system leads to a narrowing of the instructional focus of teachers and principals" (p. 4). The teaching of science was minimized (Milner, Sondergeld, Demir, Johnson, & Czerniak, 2012; Griffith & Scharmann, 2008), and in some cases eliminated altogether (Center on Education Policy, 2006). When it was taught, it was often taught through passive methods (Wurdinger & Carlson, 2010), which can compromise learning (Weimer, 2013). Through a collaborative state-led process, the Next Generation Science Standards (NGSS) were developed to improve science education for all students (NGSS Lead States, 2013).

The NGSS, released in 2013 and implemented in states and districts across the nation, have a strong focus on science and engineering practices, specifically outlining "performance expectations" (NGSS Lead States, 2013). Research confirms that learner-centered teaching has been shown to be highly effective for increasing engagement in the sciences (Eberlein et al., 2008; Weimer, 2013; Wurdinger, Haar, Hugg, & Bezon, 2007; Wurdinger & Carlson, 2010) and students should be "constructing understanding and meaning, not receiving it" (Soloway, et al., 1996, p. 189). Converting classrooms from teacher-directed to learner-centered requires a paradigm shift in teaching practices.

While there is much literature on the instructional shifts proposed with the NGSS, the challenges of NGSS implementation from the perspectives of those employing the changes remains limited. This qualitative study investigated the changes in practice during the implementation of a unique experiential, learner-centered curriculum called KnowAtom™, a science curriculum designed for and aligned to the NGSS. Adopting a case study methodology, the study will address five areas of questions, using data from six teachers who were using the KnowAtom™ curriculum. The areas of focus will include: how the participants reacted to the initiation of the new program as a whole; what professional development they were provided; how the KnowAtom™ program influenced their teaching practices; what changes, if any, they noticed in learning outcomes for their students; and if there were changes in the teachers' beliefs or attitudes regarding their changes in practice. This research will add to existing literature on educational change, especially as it relates to teachers changing their practice using a learning-centered curriculum in their classrooms.

This chapter begins with a statement of the problem with evidence from prior research and current literature. The significance of the study will be discussed next, followed by the research question and sub-questions. Then, the relevant terminology will be defined. Finally, the theoretical framework that serves as a lens for the study will be introduced and explained.

Problem Statement

The United States' schools have fallen behind in mathematics and science (OECD, 2016; TIMMS, 2015). According to the National Research Council (2007), even after "15 years of focused standards-based reform, improvements in U.S. science education are modest at best, and comparisons show that U.S. students fare poorly in comparison with students in other countries" International comparisons place the U.S. in the middle of the pack globally (Desilver, 2017).

In the latest Program for International Student Assessment (PISA), out of 73 participating countries, U.S. students ranked 40th in the world in math and 25th in the world in science literacy (OECD, 2016). PISA is administered every three years to 15-year-old students, and math scores have declined for the second time in the past two assessments. In fact, the U.S. score in math on the latest PISA assessment was 23 points lower than the average of all nations taking part in the survey. And in science, students are not making significant progress. In fact, the U.S. rankings in science remain relatively unchanged from previous years (OECD, 2016). The Trends in International Mathematics and Science Study (TIMMS) assessment also showed U.S. students well behind their first-world peers. On the most recent TIMMS assessment, 8^{th} grade U.S. students ranked 11^{th} out of 39 participating countries. The results of the assessment revealed U.S. students lagging almost 70 points behind their Asian peers and not showing growth from the previous TIMMS assessment (TIMMS, 2015).

Because of the need for a stronger STEM pipeline to keep the U.S. competitive globally in innovation (Gardner, 1983), there has been a recent mandate for more science, technology, engineering, and mathematics (STEM) education (Handelsman & Smith, 2016). In the United States, educational reform efforts are leading educators away from a didactic teacher-centered model, toward a constructivist paradigm, where knowledge is constructed by the learner through teacher facilitation (Hord, 2003; Weimer, 2013; Wurdinger & Carlson, 2010). While it has been known that this paradigm shift was necessary for over two decades (Soloway et al., 1996), the change process has been slow. Studies have shown that even students with passing grades are dropping out of school because of boredom (Bridgeland, Dilulio, & Morison, 2006; Wolk, 2001). One way U.S. schools can continue to engage students, and consequently create the innovators of the future, is to put the learning in the hands of the students.

“Active learning confers a deeper understanding of science than does a conventional lecture” (Waldrop, 2015, p. 272). Lam, Cheng, and Choy (2009) found, “[Active] learning will have a better chance to bring about the desired benefits for students if teachers have a strong motivation to experiment with and improve it in the classroom" (p. 488). However, active learning can be a challenge for teachers who thrived on standard lectures during their own schooling or for those who feel ill prepared to implement active learning. Across OECD countries, school principals cited staff resisting change as one of the problems that hinder student learning the most (OECD, 2016, p. 10).

In this qualitative, instrumental case study, the changes in teaching practice to adapt to a learner-centered teaching style will be explored through semi-structured interviews, direct observations, school documents, and publicly accessible data, as recommended by Yin (2013).

Purpose Statement

The purpose for this qualitative, instrumental case study is to explore the change in practice required of science teachers to implement active learning and, subsequently, prepare students to meet the demands of the Next Generation Science Standards. A qualitative approach was best suited for this study because the goal was to interpret (Erickson, F., 1986) the experiences of the teachers from their multiple perspectives while they implemented the KnowAtom™ curriculum. An instrumental case study was the most appropriate for this study because the intent was to understand something other than the curriculum (Stake, 1995, p. 3). Exploring the KnowAtom™ implementation will be instrumental in understanding the changes teachers had to make in their practice

The teachers, who volunteered to be part of this study, were fourth and fifth grade science teachers, who were involved in the implementation of the KnowAtom™ curriculum for the past two years. The setting in an urban school district located in Massachusetts that is in its fourth year of KnowAtom™ implementation.

Significance

The significance of this study to science educators is that it outlines the changes in pedagogical practices of teachers in order for science students to develop 21st century skills and be prepared for the more rigorous demands of the Next Generation Science Standards. This is especially significant in Massachusetts, where high school students must pass the Massachusetts Comprehensive Assessment System (MCAS) in mathematics, English language arts, and science in order to receive their high school diploma. The significance to administrators and curriculum designers is that it illuminates the necessity to ensure that teachers are employing student-centered/constructivist approaches in teaching science and to invest in program and materials that presuppose these approaches.

It is evident that NGSS emphasize that teachers must incorporate active learning into their classrooms. Looking at the perspectives on best practices that teachers bring to the school setting, as well as their perspectives on the realities of change, offers an insightful glimpse to the world that has, to this point, largely failed to change behind the classroom door.

Research Question

The main question the researcher will explore will be: "How have fourth & fifth grade science teachers changed their practices to implement KnowAtom™, a learner-centered, NGSS-aligned curriculum in their classrooms?"

Research Sub-questions

1. What were the participants' initial feelings about implementing the KnowAtom™ curriculum?
2. What professional development opportunities were provided to the participants?

3. How did the participants shift their teaching practices to while implementing KnowAtom^{TM}?
4. What changes did the participants notice in learning outcomes for their students?
5. How did the teachers' attitudes or beliefs change after implementing the KnowAtom^{TM} curriculum?

Definition of Key Terminology

This study explores to what extent did teachers, using the KnowAtom^{TM} science program, had to change their teaching practices. Definitions of relevant key terms included in the research are provided.

21st Century Skills

According to the Partnership for 21st Century Learning's (P21) Framework for 21st Century Learning, 21st century skills are the "skills, knowledge and expertise students should master to succeed in work and life in the 21st century" (Partnership for 21st Century Learning, 2007). There are four student outcomes in the framework. The first is a focus on core subject content knowledge and 21st century themes, such as global awareness and environmental literacy. The second is a focus on learning and innovation skills, including the 4-C's: creativity and innovation, critical thinking and problem solving, communication, and collaboration. The third focus is on information, media, and technology skills. The fourth focus is on life and career skills including flexibility and adaptability, initiative and self-direction, productivity and accountability, and leadership and responsibility. These four student outcomes are supported by learning environments, professional development, curriculum and instruction, and standards and assessment (Partnership for 21st Century Learning, 2007).

KnowAtom™

KnowAtom™ is a complete K-8 solution designed for master of the Next Generation Science Standards (NGSS), which includes fully aligned curriculum, integrated hands-on materials, and targeted professional development. According to KnowAtom™ (Oct. 2017 [blog]), there are seven features that NGSS-designed curriculum share:

1. Student learning is driven by a real-world context, a phenomenon that students will explore hands-on in the lessons
2. Students learn how to plan their own investigations
3. Standards are taught in groups, not in isolation
4. Coherence across a unit, between units in a year, and from one year to the next
5. Providing enough time for students to productively struggle
6. Support for teachers in next generation instruction
7. Time, space, equipment, and expendable materials that can be used for investigative and design projects

A description of the KnowAtom™ curriculum found on its website states:

> The KnowAtom™ curriculum launches students on a yearlong process of hands-on discovery in three dimensions. The lessons build a big-picture narrative of what science and engineering are and use storylines to bring the content to life in scenarios where students investigate phenomena and design solutions to problems. (KnowAtom™, 2017)

Learning Outcomes

For this study's theoretical framework, learning outcomes were broadly construed to include "not only cognitive and achievement indexes, but also the wide range of student affective characteristics" (Guskey, 1985, p. 58). Therefore, outcomes accepted for this study ranged from student scores on quizzes, exams, and standardized tests to student motivation, attitudes, and even student attendance. According to Guskey (1985), learning outcomes may include whatever “evidence a teacher uses to judge the effectiveness of [the curriculum] or his or her teaching” (p. 58).

Next Generation Science Standards (NGSS)

The NGSS is a framework that outlines disciplinary core ideas that all students should learn with “increasing depth and sophistication from kindergarten to twelfth grade” (NGSS Lead States, 2013, p. 382). The biggest change with the NGSS from prior standards is its three-dimensional approach. Each NGSS performance expectation must combine a relevant practice of science or engineering, with a core disciplinary idea and crosscutting concept, appropriate for students of the designed grade level.

Standards-based Reform

Hamilton, Stecher, and Yuan (2008) found that while there is no universally accepted definition of standards-based reform (SBR), most discussions of standards-based reform include some or all of the following features:

- *academic expectations for students* (the standards are often described as indicating “what students should know and be able to do”)
- *alignment of the key elements of the educational system* to promote attainment of these expectations,
- the use of *assessments of student achievement* to monitor performance,
- *decentralization* of responsibility for decisions relating to curriculum and instruction to schools,
- *support and technical assistance* to foster improvement of educational services,

- *accountability* provisions that reward or sanction schools or students on the basis of measured performance.

Conceptual Framework

The conceptual framework for this study was Guskey's (1985) model of teacher change. There are four components to Guskey's teacher change model, shown in figure 1. The model initiates with staff development on a new initiative or program. The teachers' change to classroom practices as a result of the new initiative or program is the second step of the model. The third step is the changes to student learning outcomes. This, subsequently, causes a change in teachers' beliefs and attitudes about the change, which is the final step of the model.

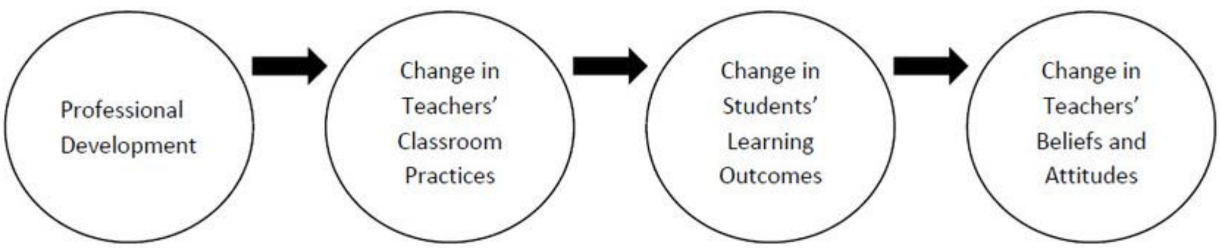

Figure 1: Guskey's (1985) model of teacher change.

Professional Development (PD)

The first step in Guskey's (1985) model of teacher change is professional development (PD). According to Ball & Cohen (1999), significant professional development is needed to move school reform beyond rhetoric to permeating practice. Furthermore, professional development cannot be disconnected from the classroom practice (Cohen & Hill, 1997). During a curriculum change, there will be many hurdles to overcome. Teachers will have to become familiar with the standards and, subsequently, put them into practice. Ladson-Billings (1994) called this transforming "the concept into 'knowledge in use'- to move it from the theoretical and conceptual to the practical" (p. 101). Principals and administrators are encouraged to provide time and supportive professional development in ways that will build capacity within the school for the successful implementation of curriculum standards (Monson & Monson, 1997, p. 67).

Professional development should provide time for teachers to engage collaboratively in concrete experiences preparing them to work with the standards. According to Monson and Monson (1997), professional development should help teachers understand how to reflect on their practice in a critical way. If professional development is not meaningful and connected to practice, it can hamper curriculum reform (Tong, 2010). In order to take education forward, teachers need to have opportunities to reconsider their current practices, which requires significant and meaningful professional development (Ball & Cohen, 1999).

Changes in Science Teachers' Practices

The KnowAtom™ curriculum is a program that requires teachers to significantly change their practices, because it is aligned to and specifically designed for the NGSS. It is learner-centered, as opposed to teacher-directed. Learner-centered teaching is teaching that is "focused on learning- what the students are doing is the central concern of the teacher" (Weimer, 2013). According to Weimer (2013), there are five parts to learner-centered teaching.

1. It is teaching that engages students in the hard, messy work of learning.
2. It is teaching that motivates and empowers students by giving them some control over the learning processes.
3. It is teaching that encourages collaboration, acknowledging the classroom (be it virtual or real) as a community where everyone shares the learning agenda.
4. It is teaching that promotes students' reflection about what they are learning and how they are learning it.
5. It is teaching that includes explicit learning skills instruction (p. 15).

The learner-centered approach is “rooted in the American Psychological Association’s (1997) 14 learner-centered principles, which are summarized by the four domains of metacognitive and cognitive, affective and motivational, developmental and social, and individual differences factors” (Cornelius-White, 2007, p. 115). Learner-centered teaching is theoretically motivated by “sociocultural and constructivist theories of learning” (Soloway, et al., 1996, p. 189).

Constructivism is, according to Anderson (1996) an “interactive process during which teachers and learners worked together to create new ideas in their mutual attempt to connect previous understandings to new knowledge” (p. 48). Yager (1991) posited “typical schooling is ineffective in altering misconceptions”, and called the constructivist model the “most promising new model” of learning (p. 53).

Sociocultural theory stresses that knowledge is inseparable from practice and learning is a social phenomenon that takes place during interaction between people and the culture in which they live (Wilson & Peterson, 2006). Sociocultural approaches to learning and development are based on the concept that “human activities take place in cultural contexts, are mediated by language and other symbol systems, and can be best understood when investigated in their historical development” (John-Steiner & Mahn, 1996, p. 191). When learning a new skill, learners depend on others with more experience. Through the interdependence of social and individual processes, there is a co-construction of the new knowledge or skill.

Furthermore, learner-centered teaching promotes five changes to practice that needs to occur: the role of the teacher, the function of content, the purpose and process of evaluation, the responsibility for learning, and the balance of power (Weimer, 2013). According to Marx, Blumenfeld, Krajcik, and Soloway (1997), Teachers should break down tasks, use modeling and coaching to teach strategies for thinking, provide feedback, and gradually release responsibility to the learner. Teaching requires "improvisation, conjecturing, experimenting, and assessing" (Ball & Cohen, 1999, p. 10). Teachers resist buying into professional development because they are reluctant to discard practices in their classrooms" (Guskey, 2002), but teachers must be able to adapt and continually develop their practice (Ball & Cohen, 1999).

Change in Student Learning Outcomes

The third part of Guskey's (1985) model of teacher change is change in the learning outcomes of students. The constructivist's emphasis is not on learning outcomes (Kolb, 2015), but about the ways people learn; and, therefore, can be more than merely test scores. Several studies have shown positive outcomes with experiential, learner-centered teaching. These outcomes ranged from students having deeper learning of concepts (Trigwell, 2010), having increased motivation and engagement (Cornell & Clark, 1999), becoming more self-directed learners (Zimmerman, 2008), increasing their problem-solving skills (Bransford, Brown, & Cocking, 1999), increasing class attendance (Dochy, Segers, den Bossche, & Gijbels, 2003), and having stronger group cohesiveness (Wurdinger et al., 2007).

Littky and Grabelle (2004) define the goal of education as helping children to be lifelong learners, passionate, risk takers, problem solvers, critical thinkers, independent, creative, and moral, as well as being able to speak well, write well, read well, and work well with numbers. To reach this goal, there must be sequentially more complex activities to help the child reach his full potential. Brofenbrenner (1979) wrote:

> Learning and development are facilitated by the participation of the developing person in progressively more complex patterns of reciprocal activity with someone with whom that

> person has developed a strong and enduring emotional attachment and when the balance of power gradually shifts in favour of the developing person (p. 60).

When teachers see this shift in their students' learning outcomes, they will be more inclined to change their attitudes and beliefs. Practices that are useful in helping students attain the desired outcome are retained and repeated: those that are not are abandoned (Guskey, 2002).

Change in Teachers' Beliefs and Attitudes

The final component of Guskey's (1985) teacher change model is the change in teachers' beliefs and attitudes. Attitudes and beliefs about teaching generally come from classroom experience. If teachers try a new instructional strategy, their beliefs about it are likely to change either positively or negatively (Guskey, 2002).

For almost four decades, Jack Mezirow's (1978) transformative learning theory has become a "comprehensive and complex description of how learners construe, validate, and reformulate the meaning of their experiences" (Cranton, 1994, p. 730). It is learning that transforms the learner in "deep, profound, and lasting ways" (Weimer, 2013, p. 25). It can take place through a single event or gradually over time and lead to a "transformation of our personality or worldview" (Anfara & Mertz, 2015, p. 81). In the case of the participants in this study, the event that triggered the change was the adoption of the NGSS standards and successive implementation of the KnowAtom™ curriculum.

Among other factors, such as interests, values, and beliefs, individuals' reactions to change are a result of their emotions with respect to a change (Klarner, By, & Diefenbach, 2011, p. 333). Teachers often have "ambivalent" (Piderit, 2000) feelings about a change, especially as they are unsure how the change will impact their practice and their students. Failure to emotionally adapt to change leads to resistance among employees (Spiker, 1994), whereas positive emotions can help employees cope with change. Kotter and Cohen (2002) suggest people react to change better when they are shown a truth that influences their feelings (p. 3), and Tong's (2010) research showed change cannot occur without teachers' understanding and support.

In a change process, resistance can be a valuable resource. Henry (1997) wrote that "resistance serves to maintain equilibrium until the reasons for change are both conscious and compelling" (p. S145). Employee emotions at different levels can impact their behavior during the change process. "Positive and negative emotions should rather be seen as continual and mutually informative" (Klarner, By, & Diefenbach, 2011, p. 333). As noted by Fullan (2001), "educational change depends on what teachers do and think- it's as simple and as complex as that" (p. 115). Without teacher acceptance of change initiatives, innovative programs will not be successful in the classroom.

Overview of Research Plan

A qualitative research design using an instrumental case study was used to explore the changes in teaching practices of fourth and fifth grade science teachers in New England during the implementation of KnowAtom™, a NGSS-designed curriculum. After going through both Northeastern University's institutional review board (IRB) and the school district's IRB, participants were selected using "purposeful" (Merriam, 2002, p. 15), criterion-based convenience sampling. The data was collected using semi-structured interviews of the science teachers, a district administrator, and a representative from KnowAtom™. Additional data sources included publicly accessible documents on student outcomes before and after the KnowAtom™ implementation, as well as direct observations of the science teachers. Finally, the researcher kept a research journal, which contained descriptive and reflective notes from the observations, as well as analytic memos. The triangulation of these data sources provided consistency to the findings.

For data analysis, the researcher followed the data analysis recommended by Miles and Huberman (1994, p. 10-11). She first reduced the data by manually coding it from the observations, interviews, and public documents, looking for emerging patterns. Next, the researcher displayed the data in matrices and/or networks. A qualitative data analysis software application or product was used to visually show networks of patterns. Lastly, the researcher drew conclusions and verified them by reviewing the field notes as well as the existing literature.

Assumptions

One assumption in this study is that the study participants responded candidly during the interviews. Another assumption is the study participants held a normal classroom session during the observations and did not make changes because they were being observed. A final assumption is the participants were knowledgeable and experienced enough with the KnowAtom™ curriculum to give valid reasoning to how their teaching has changed from prior to using it.

Scope and Limitations

The scope of the study was limited to fourth and fifth grade science teachers, who had been using the KnowAtom™ NGSS-aligned curriculum. Only those teachers who had been implementing the program for at least two years were included.

A limitation of this study is the low number of participants. Many noteworthy researchers recommend the right number is when the researcher has hit theoretical saturation (Sandelowski, 1995; Fossey, Harvey, McDermott, & Davidson, 2002), the point at which the researcher is no longer learning very much (if anything) from subsequent interviews. Romney, Weller and

Batchelder (1986) found that small samples, as few as four, can be quite sufficient in providing complete and accurate information with a high confidence level if they possess a high degree of competence for the domain of inquiry (p. 326).

Summary

When comparing students in science, reading, and mathematics from the United States (U.S.) with students from other countries, it was evident U.S. students were behind (OECD, 2016). In response, a common set of standards were implemented in mathematics and ELA/literacy (NEA, 2010). Student results in mathematics and ELA/literacy were tied to federal funding (Griffith & Scharmann, 2008), which resulted in other subjects, like science, taking a back seat. As a response, the National Research Council, the National Science Teachers Association, and the American Association for the Advancement of Science, in collaboration with 26 states, developed the Next Generation Science Standards, which are now being implemented in 19 U.S. territories, districts, and states across the country (NGSS Lead States, 2013). The NGSS have a strong focus on 21st century skills and performance expectations that are tied to science and engineering practices. Students have opportunities for growth as they construct knowledge through experimentation and collaboration, and science teachers become more adept at facilitating the learning process and cultivating student habits of mind. This study will show that a learner-centered model through the KnowAtom™ program can lead to more effective science teaching, better student engagement, better academic outcomes, and the development of 21st century skills needed for global competitiveness.

Chapter 2: Review of Related Literature

Science is the driving force in the United States' ability to continue to innovate, lead, and create the jobs of the future. With the need for a stronger STEM talent pipeline, the previous outdated science standards went through a major overhaul, resulting in more rigorous performance expectations to better prepare students for the demands of college and careers in the 21st century. The real innovation of the NGSS is the requirement that students operate at the intersection of practice, content, and connection (NGSS Lead States, 2013). The main focus of this literature review was to examine the recent changes in science standards, the subsequent changes in science curriculum and instruction, and change models outlining the change process.

This chapter begins with a review of the literature that outlines the history of science standards leading up to the current NGSS as well as important changes in Massachusetts' educational law. Next, best practices in science education and science teaching will be discussed. The chapter will conclude with a review of the change models which underlie this study's conceptual framework.

Changes in Science Standards

Educational reform is not a new occurrence. Since the 1980s, there has been an initiative toward standards-based reform (SBR). The central idea behind science education standards is to describe clear, consistent, and comprehensive science content and abilities.

History of Science Standards

In 1983, the National Commission on Excellence in Education published its *A Nation at Risk: The Imperative for Educational Reform* report, which charged that U.S. schools were failing to prepare students to compete globally (National Commission on Excellence in Education, 1983). The report recommended minimum requirements in core subjects as a graduation requirement, including three years of science and a half year of computer science. Additionally, schools were encouraged to adopt more rigorous and measurable standards of high expectations for academic performance. In response, the American Association for the Advancement of Science (AAAS) launched "Project 2061" a couple of years later (AAAS, 2014). Project 2061, an initiative to help Americans become literate in science, mathematics, and technology, set out to identify what was most important for the next generation to know and be able to do in these subjects. By 1989, Rutherford and Algren published, *Science for All Americans*, which defined science literacy and became the first step toward national standards in science for all students (Rutherford & Algren, 1989).

Science for All Americans (Rutherford & Algren, 1989) provided the basis for *Benchmarks for Science Literacy* (AAAS, 1993). That same year, Massachusetts began making changes to its graduation requirements. In 1993, the Massachusetts Educational Reform Act (MERA) was passed, specifying that all students' performance be measured on learning standards, further emphasizing the use of standards-based education. MERA also established a competency determination that 10^{th} grade students must meet, as determined by a standards-based assessment system, as a prerequisite for graduation.

Building on the work of the *Benchmarks for Science Literacy* (AAAS, 1993), the National Research Council (1996) produced the *National Science Education Standards*, identifying what students need to know and be able to do to be scientifically literate at particular grade levels. These standards were built on the premise that "science is an active process" and students would need "hands-on" and "minds-on" activities (National Research Council, 1996, p. 2).

Massachusetts continued working on aligning assessments to standards and in 1998 Massachusetts implemented the Massachusetts Comprehensive Assessment System (MCAS) to assess student mastery of the ELA/literacy and mathematics standards contained in the Massachusetts Curriculum Frameworks. Of note is the fact that students were initially assessed only in English language arts and mathematics, and would not be tested on science standards for another decade.

In 2002, the United States Congress reauthorized the Elementary and Secondary Education Act of 1965 again as the No Child Left Behind Act (NCLB). This directed each state to develop rigorous standards and assessment systems to be administered annually to students in grades three through eight in the subject areas of ELA/literacy and Mathematics. Because of the hyper focus on these two core subjects, especially in schools with high proportions of students below grade level in reading and mathematics, science education, along with other core subjects, suffered (Griffith & Scharmann, 2008). These federally mandated requirements often resulted in a narrowing of curriculum, an unintended consequence of NCLB (Fullan, 2007).

As the standards movement became an integral part of every states' educational focus, the law allowed states to develop standards individually with a wide variance of expectations within grade level when compared state to state. It became apparent that proficiency in ELA/literacy in a grade level in one state could not be equated with proficiency at that same grade level in another state (Stansfield, 2011). Given this variance of rigor, various educational and national organizations began discussing the need for a set of national standards, giving students access to a common educational curriculum (Harris, 2012). In 2008, the National Governors Association (NGA) and the Council Chief State School Officers (CCSSO) recommended that states adopt a common core of internationally benchmarked standards in mathematics and language arts for grades K-12 (National Governors Association, 2008). Work began on developing a set of common standards and in June of 2010, the Common Core State Standards were released for mathematics and ELA/literacy. That same year, 2010, Massachusetts added an additional competency and graduation requirement for all students, requiring them to meet or exceed a passing score on one of four high school science and technology/engineering MCAS tests: biology, chemistry, introductory physics, or technology engineering (Chester, 2014).

At that time in 2010, national science standards had not been updated for fifteen years. Given the nature of continuous discovery and innovation in science, there had been many changes in the fields of science and science education. Given that gap, the National Research Council, part of the National Academy of Sciences, began work on and released the *Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (Framework)* in 2012. The *Framework* was grounded in the most current research on science and scientific learning at the time, identifying the science content K-12 students should know and the science and engineering practices students should be able to do (NGSS Lead States, 2013). The *Framework* provided an outline for developing science standards, recommending that the standards should:

1. Set rigorous goals for all students
2. Be scientifically accurate
3. Be limited in number
4. Emphasize all three dimensions
5. Include performance expectations that integrate the three dimensions
6. Be informed by research on learning and teaching

7. Meet the diverse needs of students and states
8. Have potential for a coherent progression across grades and within grades
9. Be explicit about resources, time, and teacher expertise
10. Align with other K-12 subjects, especially the Common Core State Standards
11. Take into account diversity and equity (NRC, 2012, pp. 297-307)

Building on the National Research Council's *Framework*, a group of 26 lead states, Massachusetts included, and 41 writers, in a process managed by Achieve, Inc., worked to develop the Next Generation Science Standards (NGSS). After subjecting the standards to numerous state reviews, two public comment periods, and feedback from the National Science Teacher Association, the standards were released for states to consider for adoption in April 2013. Unlike the Common Core State Standards with NCLB, there was no financial incentive for adoption; however, over 40 states showed interest in the standards. As of November 2017, nineteen states and the District of Columbia had adopted the NGSS, representing over 36% of students in the United States (NSTA, 2017).

Next Generation Science Standards

There are two major differences between the NGSS and previous science standards: three-dimensional learning and performance expectations. The NGSS presents standards as knowledge-in-use by expressing them as performance expectations (PEs) that integrate all three dimensions from the *Framework*. Within the three-dimensions are disciplinary core ideas (DCIs), crosscutting concepts (CCs), and science and engineering practices (SEPs). Disciplinary core ideas refer to the content specific to that discipline; crosscutting concepts refer to the system behaviors and relationships that reach across disciplines; and the eight science and engineering practices outlined in the standards are as follows:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematical and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

The NGSS require for students to demonstrate their scientific knowledge by applying it in context. The belief behind this is that "practices alone are activities and content alone is memorization" (NGSS Lead States, 2013), but combining practice and content gives the learning context. The goal is for students to engage in science and engineering practices and use disciplinary core ideas and crosscutting concepts in order to "make sense of new information, explain phenomena in the world around them, solve problems, and make informed decisions" (Roseman & Koppal, 2015, p. 24).

The Next Generation Science Standards mark an innovation in science and engineering instruction. Past standards separated content from process by presenting learning goals as knowledge or skills statements. "It is hard for students to gain an appreciation for science and engineering when they are not asked to do what scientists and engineers do: to answer questions, explain phenomena, and solve problems" (Ewing, 2015, p. 54). In contrast, the NGSS set performance expectations for assessment purposes as what students should know and be able to do. In particular, the new standards call for moving away from "learning context and inquiry in isolation to building knowledge in use" (Krajcik, Codere, Dahsah, Bayer, & Mun, 2014, p. 158).

An example of a fifth-grade life science performance expectation is depicted below. The three dimensions are represented in the colored boxes, providing a blueprint for the curriculum and instruction design.

5-LS2 Ecosystems: Interactions, Energy, and Dynamics

5-LS2 Ecosystems: Interactions, Energy, and Dynamics

Students who demonstrate understanding can:

5-LS2-1. Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment. [Clarification Statement: Emphasis is on the idea that matter that is not food (air, water, decomposed materials in soil) is changed by plants into matter that is food. Examples of systems could include organisms, ecosystems, and the Earth.] [Assessment Boundary: Assessment does not include molecular explanations.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 3–5 builds on K–2 models and progresses to building and revising simple models and using models to represent events and design solutions. ▪ Develop a model to describe phenomena. (5-LS2-1) --- ***Connections to Nature of Science*** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** ▪ Science explanations describe the mechanisms for natural events. (5-LS2-1)	**LS2.A: Interdependent Relationships in Ecosystems** ▪ The food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plants parts and animals) and therefore operate as "decomposers." Decomposition eventually restores (recycles) some materials back to the soil. Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem. (5-LS2-1) **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** ▪ Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, and water, from the environment, and release waste matter (gas, liquid, or solid) back into the environment. (5-LS2-1)	**Systems and System Models** ▪ A system can be described in terms of its components and their interactions. (5-LS2-1)

Connections to other DCIs in fifth grade: **5.PS1.A** (5-LS2-1); **5.ESS2.A** (5-LS2-1)

Articulation of DCIs across grade-levels: **2.PS1.A** (5-LS2-1); **2.LS4.D** (5-LS2-1); **4.ESS2.E** (5-LS2-1); **MS.PS3.D** (5-LS2-1); **MS.LS1.C** (5-LS2-1); **MS.LS2.A** (5-LS2-1); **MS.LS2.B** (5-LS2-1)

Common Core State Standards Connections:

ELA/Literacy –

RI.5.7 Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently. *(5-LS2-1)*

SL.5.5 Include multimedia components (e.g., graphics, sound) and visual displays in presentations when appropriate to enhance the development of main ideas or themes. *(5-LS2-1)*

Mathematics –

MP.2 Reason abstractly and quantitatively. *(5-LS2-1)*

MP.4 Model with mathematics. *(5-LS2-1)*

Figure 2. NGSS 5th-grade science standard.

Dimension 1, Science and Engineering Practices, describes the major practices that scientists employ as they investigate and build models and theories about the world as well as a set of engineering practices that engineers use as they design and build systems. Dimension 2, Disciplinary Core Ideas, focuses on preparing students with sufficient core knowledge to be able to later acquire additional information on their own. It is a shift from teaching all the facts. Dimension 3, Crosscutting Concepts, provides a way of linking across the domains: physical science, life science, earth and space science, and engineering, technology, and applications of science.

Changes in Curriculum and Instruction

When curriculum standards are aligned with instructional strategies that support the required learning, they have the "potential to improve educational practices" (Pemberton, Rademacher, Tyler-Wood, & Perez Cereijo, 2006, p. 284). In *The Next Generation Science Standards: Where Are We Now And What Have We Learned*, Dr. Stephen Pruitt, who led the development of the NGSS, wrote "As we implement the NGSS, it is important to remember that education is a journey, not a destination" (2015, p. 1). There are a host of obstacles when a state adopts and implements new science standards, one of those being aligning the curriculum to the new standards. Research has shown that almost 70% of teachers use textbooks to guide the classroom content (Banilower, Smith, Weiss, Malzahn, Campbell, & Weis, 2013) and that many textbooks emphasize technical terminology rather than making connections among important ideas (Roseman, Stern, & Koppal, 2010). The NGSS calls for a deeper understanding and application of content. The focus is no longer on facts, but on core ideas and practices of science. These key shifts will cause a deliberate adjustment in instruction, requiring, if implemented with fidelity, that all science teachers reflect on their practices (Miller, 2013).

According to the National Research Council (2015), implementation of the NGSS should be guided by seven principles that reflect the vision of the Framework:

1. Ensure coherence across levels (state, district, schools), across grades, and across different components of the system- curriculum, assessment, instruction and professional development.
2. Attend to what is unique about science.
3. Develop and provide continuing support for leadership in science at the state, district, and school level.

4. Build and leverage networks, partnerships, and collaborations.
5. Take enough time to implement well.
6. Make equity a priority.
7. Ensure that communication is ongoing and relevant. (pp. 1-2)

The vision of the implementation of the NGSS differs in important ways from how science is currently being taught in many U.S. classrooms. The National Academy of Sciences (2015) described how science education will be transformed and what classrooms will look like with the adoption of the NGSS.

Table 1

Changes in Science Education (NAS, 2015, p. 11)

Science Education Will Involve Less	Science Education Will Involve More
Rote memorization of facts and terminology	Facts and terminology learned as needed while developing explanations and designing solutions supported by evidence-based arguments and reasoning
Leaning of ideas disconnected from questions about phenomena	Systems thinking and modeling to explain phenomena and to give a context for the ideas to be learned
Teachers providing information to the whole class	Students conducting investigations, solving problems, and engaging in discussions with teachers' guidance
Teachers posing questions with only one right answer	Students discussing open-ended questions that focus on the strength of the evidence used to generate claims
Students reading textbooks and answering questions at the end of the chapter	Students reading multiple sources, including science-related magazines, journal articles, and web-based resources Students developing summaries of information
Preplanned outcomes for "cookbook" laboratories or hands-on activities	Multiple investigations driven by students' questions with a range of possible outcomes that collectively lead to a deep understanding of established core scientific ideas
Worksheets	Students writing journals, reports, posters, media presentations that explain and argue
Oversimplification of activities for students who are perceived to be less able to do science and engineering	Providing supports so that all students can engage in sophisticated science and engineering practices

In order to ensure the successful implementation of the new standards, choosing aligned instructional materials will be crucial; yet, "full sequences of curriculum materials designed explicitly for the NGSS have not been developed" (National Research Council, 2015, p. 4). Until they are, teachers are encouraged to revise their current units to be consistent with the NGSS (National Research Council, 2015).

Curriculum Alignment to the NGSS

Marketing materials sent to teachers, schools and districts make claims of alignment to the NGSS; however, curriculum consumers are advised to do their due diligence before selecting materials. To help curriculum decision makers decide if materials are aligned, Achieve, Inc. (2018), who helped create the NGSS, developed the Educators Evaluating the Quality of Instructional Products (EQuIP) Rubric for science. The EQuIP Rubric is a new tool for science educators that provides criteria by which to measure the alignment and overall quality of lessons and units designed for the NGSS (Ewing, 2015). The rubric's criteria are divided into three categories: NGSS 3-D Design Alignment, NGSS Instructional Supports, and Monitoring NGSS Student Progress. Lessons and units designed for the NGSS should include clear and compelling evidence in each of the three categories. The purpose of the EQuIP rubric and review process is to: (1) review existing lessons and units to determine what revisions are needed; (2) provide constructive criterion-based feedback and suggestions for improvement to developers; (3) identify examples/models for teachers' use within and across states; and (4) to inform the develop of new lessons, units, and other instructional materials (Ewing, 2015).

With the goal of helping the science education community understand what the NGSS looks like in practice, Achieve, Inc. has offered to provide an unbiased review of a school's materials using the EQuIP rubric (Achieve, 2018). The reviews detail the evidence for how thoroughly the materials are designed for the NGSS and include suggestions for making them even more so. The reviews take eight-to-ten weeks and involve no cost to the school or district since it is covered by grant funding. High-scoring instructional materials will be featured on the Achieve, Inc. website.

For material developers who have had their materials reviewed through the Achieve Inc. process, Achieve Inc. offers an NGSS digital badge, which can be used on marketing and promotional materials. On March 13, 2018, Achieve, Inc. awarded its first digital badge that earned a rating of “E: Example of high-quality NGSS design” on the EQuIP rubric for science (Achieve, 2018). The badge is a way for curriculum decision makers to be assured that a science unit is high quality and designed for the NGSS. The badges will also be digitally verifiable. “By clicking on the badge image, a consumer will see information about the awarded unit, a link to the complete EQuIP review of that unit that describes the evidence associated with earning the NGSS Design Badge, and a link to a list of all other units that have earned the badge” (Achieve, 2018).

Instructional Alignment to the NGSS

The NGSS not only affects what is taught, but also how it is taught. NGSS demands some major modifications in teaching practice (Reiser, 2013); nevertheless, the “translation of constructivist-like ideas into classroom action appears to be anything but easy” (Null, 2004). A recent national survey (Banilower, et al., 2013) revealed that direct instruction was still the most common way science was being taught. During a curriculum change, teachers will have to become familiar with the standards and, subsequently, put them into practice, which Ladson-Billings (1994) refers to as “knowledge in use” (p. 101).

The NGSS presents standards as knowledge-in-use by expressing them as performance expectations, so science teaching has to move away from covering many isolated facts to engaging in science and engineering practices that explain phenomena and solve problems

(Krajcik, Codere, Dahsah, Bayer, & Mun, 2014). However, change is a process that takes time (Hall & Loucks, 1977; Fullan, 1985). There are five major shifts in practice with learner-centered teaching: the role of the teacher, the balance of power, the function of content, student ownership, and the purpose and processes of evaluation.

Role of the Teacher. One of the first shifts in practices is the role of the teacher. If the goal is for students to be able to be able to reason and act scientifically (Ford, 2015), learning information by being told is an ineffective strategy (National Research Council, 2007, 2012). The nature of the NGSS is authentic instruction. Teachers need to shift their role to one of a facilitator, which is easier said than done. Facilitating learning involves skills rarely practiced and can be awkward and uncomfortable (Weimer, 2013).

Facilitating learning means more work for students, and students often resist taking on more responsibility for their learning. Students will be in charge of developing arguments and presenting evidence that support their claim about a concept. Essentially, students are being asked to think like scientists. There is a big shift toward knowledge building instead of merely following a procedure during a scientific experiment. Students have to apply their knowledge and make predictions to scientific scenarios. In order to help students reach this level, teachers will need to become facilitators of the learning process and allow the students to struggle with there not always being one “right” answer.

Weimer (2013) sets out seven principles which can guide teachers in implementing the role as facilitator.

1. Teachers let students do more learning tasks. (e.g. At the end of the class discussion, it should not always be the teacher summarizing it.)

2. Teachers do less telling so that students can do more discovering. (e.g. Teachers do not have to go over their syllabus, but rather give students ten minutes to read through it and ask any questions about it.)
3. Teachers do instructional design work more carefully. (e.g. Teachers plan authentic activities that motivate student involvement, challenging them to build on their current skills.)
4. Teachers more explicitly model how experts learn. (e.g. Teachers demonstrate and discuss explicitly how skillful learners approach learning tasks.)
5. Teachers encourage students to learn from and with each other. (e.g. Teachers plan meaningful group work or group exams to give students time to work together.) who spend more time working together tend to do better.)
6. Teachers and students work to create climates for learning. (e.g. Teachers need to put the responsibility on the students for what happens in the class.)
7. Teachers use evaluation to promote learning. (e.g. Teachers can provide feedback and design follow-up activities that increase the likelihood that students will learn from the experience and be able to improve as a result of it.)

Balance of Power. The second shift in teaching practice in a learner-centered classroom is changing the balance of power in the classroom. “Whether they realize it or not, teachers exert enormous control over the learning process of students” (Weimer, 2013, p. 10). They decide not only what students will learn, but how they will learn it. They set the pace and control the flow of communication in the classroom. The course syllabus is a perfect example of this. The syllabus often lists readings and concepts to be considered, but rarely state why the subject is important or interesting or list any learning strategies that will be used in the course (Singham, 2007).

When teaching is learner-centered, power is shared with students. The term power is used as a “linguistic convenience” (Useem, 1979), but refers to the concept that teachers still make “decisions about learning, just not all of them, and not always without student input” (Weimer, 2013, p. 94). Power is distributed to students in amounts proportional to their abilities to handle it. Sharing power can look chaotic, and there may be more noise in a classroom as students engage in group work and have discussions. Pintrich (2003) summarized his research when he wrote, “the general trend is that students who believe they have more personal control of their own learning and behavior are more likely to do well and achieve at higher levels than students who do not feel in control” (p. 673).

Function of Content. The third shift in teaching practice is the function of content. Teachers have a lot of content to cover, but the NGSS requires that teachers use the content instead of merely covering it. Learner-centered approaches are less efficient than didactic instruction. However, one of the conceptual shifts of the NGSS is that the standards focus on a deeper understanding of less content and on application of content. This is based on the philosophy that you learn science by delving deeply into one area. Instead of teaching an entire unit on weather that covers everything, teachers will be asked to choose one type of weather event (e.g., hurricanes) and focus in. Coverage of material does not always equal learning. As Wiggins and McTighe (2005) wrote, “Teaching on its own, never causes learning. Only successful attempts by the learner to learn cause learning” (p. 228). To this end, science should be taught all the way through school, starting in kindergarten. Research shows science concepts are formed gradually from birth (Trnova & Trna, 2015,) and being exposed to science not only helps children with vocabulary acquisition and critical thinking (Eshach & Fried, 2005; French, 2004), but also develops positive attitudes towards science (Eshach & Fried, 2005).

Student Ownership. The fourth shift in practice is students becoming more responsible for their learning. “The hard and messy work of learning can only be done by students” (Weimer, 2013, p. 10). This shift in ownership means first getting students to accept responsibility for their learning. To facilitate this, teachers must first recognize instructional practices that make students dependent learners and take these practices out of their classroom. Teachers must create classroom climates conducive to learning.

Teachers need to let students start experiencing the consequences of the decisions they make about learning. Teachers constantly absolve students of responsibility. Weimer (2013) gives an excellent example of this. When students constantly arrive late for class, teachers adapt by not doing important work at the beginning of the class period. This reinforces behavior that makes students less responsible. Coffman (2003) provides another example: “Even something as insignificant as bringing pencils to your students to borrow on exam days teaches students that they don’t need to be responsible for bringing them” (p. 3). Teachers need to hold high-standards and be consistent with the messages they sent students.

Purpose and Process of Evaluation. The final shift in practice is revisiting the purpose and process of evaluation. Teachers have an obligation to certify mastery of material, but with learner-centered teaching, teachers want to maximize the learning potential of any experience where students produce a product, perform a skill, or demonstrate their knowledge.

Since research has shown telling does not accomplish the desired results; therefore, teachers need to provide students with the opportunities to assess their own work and the work of others. Students need to learn to recognize what is good and what needs to be done to make something better. The NGSS asks teachers to form assessments that focus on accumulated knowledge and various practices. The assessment should encompass the full disciplinary core ideas- not just the pieces. Still, students cannot be expected to master a deep application problem on an exam if they have not been given the same type of challenge in classroom activities.

Change Models

Change is a common thread with all organizations, especially schools. As change theorist Michael Fullan (2007) noted, “Putting ideas into practice was a far more complex process than people realized” (p. 5). In *Organization Change: Theory and Practice*, Burke (2014) indicated that planned change is usually a linear process that goes through a series of steps, but also noted that things do not always proceed as planned. Kurt Lewin, who contributed to scholarship on action research, field theory, and his concept of topology, also provided one of the first fundamental models of planned change (Lewin, 1947). Thomas Guskey built on Lewin’s model of change as a process (Guskey, 1985), yet applied it specifically to changes in teachers’ practices, attitudes, and beliefs. Michael Fullan later mirrored Lewin’s model but, like Guskey, also applied it to educational change as a process. These three change models will be discussed further.

Lewin’s Change Model

Kurt Lewin, widely considered the father of change management, is credited with the popular “Unfreeze→Change→Refreeze” (Lewin, 1947, p. 34), also called the “changing as three steps (CATS) model, which refers to the three-stage process of change (Cummings, Bridgman, & Brown, 2016). While the three steps look simplistic, Schein (1987) noted that, in actual practice, the steps are much less linear than the model suggests and the stages could overlap and blend.

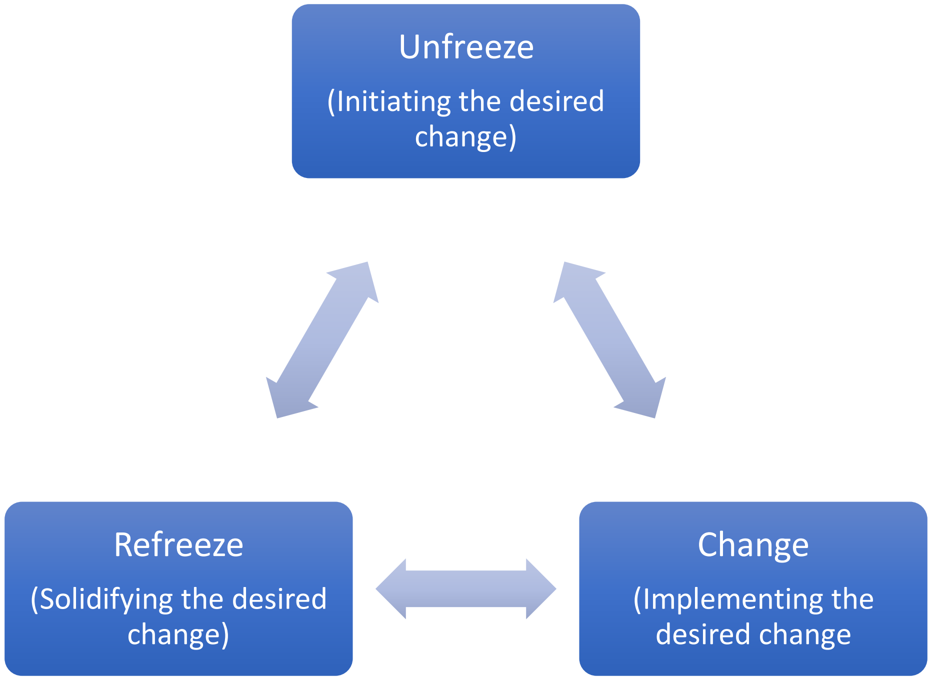

Figure 3. Lewin's "Change As Three Steps (CATS)" model.

Unfreeze. The first step in the process of changing behavior is to unfreeze the existing situation or behavior (Burke, 2014; Levasseur, 2001). In the Lewinian model, change was initiated at the foundation- challenging the beliefs, values, attitudes, and behaviors that define the organization. Lewin (1947) even suggested that deliberately stirring up emotions might be necessary to overcome "complacency and self-righteousness" (p. 35). Change is a difficult process for people, but forcing an organization to re-examine its core effectively creates a controlled crisis, with the possibility of igniting strong motivation to seek out a new equilibrium (MindTools, n.d.). Creating the motivation to change causes an organization to "unfreeze." There are many initiators of change, including new policies, a form of crisis, or a gap between where an organization presently is and where it needs to go.

Schein (1996) believed that unfreezing had to go through three processes to present a motivation to change. The three processes are disconfirmation, induction of guilt or survival anxiety, and creation of psychological safety. Schein (1996) stated the disconfirmation process must center around a feeling, which he termed “survival anxiety” (p. 29), that if we do not change, we will fail to achieve some goals or ideals we have set for ourselves, which he termed “survival guilt” (p. 29). This induction of survival anxiety can cause a person to feel bad that something in his or her life is imperfect. Dealing with this learning anxiety is what can ultimately lead to change, but first, psychological safety must be created or no change will take place. Principals and other school administrators providing encouragement will help get teachers ready for a desired change (Higgins, Judge, & Ferris, 2003).

Change. The second step is to move toward the desired level of behavior or attitude (Hussain, et al., 2016). It might include a form of training or professional development or implementing action plans for changing processes or improving systems (Burke, 2014). According to Schein (1987), change involves cognitive restructuring. Those involved in the change must see things differently than they saw them before and, as a result will act differently (Burke, 2014). But, change does not happen overnight. In his book, *Making Habits, Breaking Habits: Why We Do Things, Why We Don’t, and How to Make Changes Stick*, author and psychologist, Jeremy Dean (2013), found it can take months to form a new habit.

To move through the change process, there needs to be effective communication. Kotter and Cohen (2002) posit “remarkably, smart people undercommunicate or poorly communicate all the time without recognizing their error” p. 4). One of the issues in curriculum change is that it goes against “the way it has always been” and educators need to be shown the importance of the change. School leadership must ensure the change goals are clearly communicated to the staff. If the staff understand the reason for the change, it will help them buy in to the change.

When transforming an organization, leaders need to empower action. In order to facilitate transformation, barriers need to be removed. This includes systemic barriers, barriers of the mind, and information barriers. Kotter and Cohen (2002) recommend creating short-term wins. These are victories that nourish faith in the change effort. Monitoring the change by setting benchmarks with indicators of accountability shows that progress is real (Schifalacqua, Costello, & Denman, 2009, p. 27).

Refreeze. The third step in Lewin's change management model is to return the organization to a sense of stability, which he termed "refreeze". This final step is about making the changes stick. Too often, educators see changes as another fad that came along, and they do not expect the change to stay. However, a change can be kept in place by creating a supportive and strong organizational culture. If additional training is needed, leadership must provide the supports in order to sustain the change. Moreover, the leadership must be the example. "Albert Schweitzer once said, 'Example is not the main thing influencing others. It is the only thing'" (Kotter & Cohen, 2002, p. 165).

Lewin's model supported the notion that initiating a disruption in teachers' attitudes and beliefs started the change process. After looking at research on the role of professional development for experienced teachers (Huberman & Crandall, 1983; Huberman & Miles, 1984), Guskey (1985) created an alternative model of the change process related to teachers going through the change process. Unlike Lewin's model, Guskey's model did not start with changing teachers' attitudes and beliefs, but rather ended with it.

Guskey's Model of Teacher Change

Thomas Guskey, who researched in-service education, classroom results, and teacher change for his PhD dissertation in 1979, also asserted that systemic change involved a series of steps, but focused his model on staff development as the driving force in change. He believed it was professional development that caused a teacher to "unfreeze" their current practices.

Building on the work of Griffin (1983), Guskey wrote "Educators generally agree that the three major outcomes of effective staff development are changes in (1) teachers' beliefs and attitudes, (2) teachers' instructional practices, and (3) student learning outcomes" (1985, p. 58). Guskey brought to light the important implications for staff development based on the sequence in which these changes occur. Guskey (1985) posited, "Staff development efforts concerning new programs or innovations typically set out to gain acceptance, enthusiasm, and commitment from teachers up front, prior to the implementation of the new program or innovation" (p. 58). However, he found teachers only changed their beliefs about new ideas when they saw them working (Guskey, 1985), meaning positive changes in student outcomes. This propelled Guskey to set forth a new model that showed a specific sequence of teacher change. The model starts with staff development, which leads to changes in teachers' classroom practices. This causes a change in student outcomes, which culminates in changes in teachers' beliefs and attitudes.

Staff Development. Guskey's (1985) "New Model of Teacher Change", which will serve as the conceptual framework for this study, will now be discussed in greater depth. Effective professional development, defined by Darling-Hammond, Hyler, and Gardner (2017) as "the structured professional learning that results in changes in teacher practices and improvements in student learning outcomes", is key to teachers refining pedagogies to prepare students to be successful in the 21st century. The first step in Guskey's teacher change model calls for professional development. With Guskey's model, there are three important principles to consider when planning and implementing effective staff development.

Change is Difficult. First, leaders must realize change is a slow, difficult, and gradual process for teachers. While teachers have a desire to improve student learning, most oppose innovations that require radical alterations in their teaching practices. To counteract these feelings, staff development must clearly illustrate how the practices can be implemented without too much disruption or extra work (Guskey, 1985, p. 59). The NGSS calls for big shifts in teaching that require extensive professional development (Penuel, Harris, & DeBarger, 2015). There has to be a strong focus on educators and how to make the NGSS real in classrooms (Pruitt, 2015). Learning how to create the NGSS's 3-D culture in a classroom takes time and effort.

To make this shift in practice, teachers will need to be provided with meaningful professional development and time to collaborate and reflect on their practice (Penuel, Harris, & DeBarger, 2015; Reiser, 2013). Ball and Cohen (1999) support this notion. They propose that in order to take education forward, teachers need to have opportunities to reconsider their current practices, requiring significant and meaningful professional development. Monson and Monson (1997) also shed light on the importance of professional development, especially because "working with standards … can be challenging to practitioners" (p. 66).

Kesson and Henderson (2010) suggest the professional training of most educators falls short of preparing them with the knowledge, dispositions, and capacities to respond to challenges. Today's professional development in public schools often focuses on the problem of test performances and scripted or prescribed curriculum and instruction enforced by state accountability mandates, which contributes to the deskilling of teachers. There are occasional in-service days to highlight some new and best practices in education, but the usual practice typically continues (Fullan, 2008). This type of professional development will not help teachers. Professional development can often be removed from the setting in which teachers work, which can lead to superficial learning but not real change because "real learning comes from repeated practice with additional coaching" (Liker & Meier, 2007, p. 246). Professional development should be directed toward helping teachers understand what they need to know about implementing a new curriculum that is aligned to the standards.

Teachers need feedback. Second, leaders need to realize that teachers need to receive regular feedback on student learning outcomes. Guskey wrote, "Practices that are new and unfamiliar will be readily abandoned unless evidence of their positive effects can be seen" (1985, p. 59). Teachers receive feedback by administering regular formative assessments (Guskey, 1985). With the NGSS, these formative evaluations could be a student answering a question that shows a deep understanding of the material during a class discussion. It could also be a student showing his or her understanding of a concept through a hands-on class activity, lab activity, experiment or even drawing a picture of a process. When a teacher sees that an innovation is having a positive effect on student learning, change in their attitudes and beliefs will follow (Guskey, 1988).

Continued support and follow-up. The third important principle to consider when planning staff development is that teachers will need continued support after the initial training. Few teachers can move straight from learning about a new program to immediately implementing it in their class effectively. Instead, teachers need time to experiment with how the new practice will be fit within their unique classroom conditions, which has been referred to as "mutual adaptation" (Guskey, 1985, p. 59).

Professional development should help teachers understand how to "accommodate conflicting demands and resolve dilemmas inherent in their work [by] asking them to reflect upon their practice in a critical way" (Monson & Monson, 1997, p. 69). Even with these supports in place, employees will still require guidance and leadership as they progress through the change. Burke (2014) stated, "without leadership, planned organization change will never be realized" (p. 276.) Unless administrators provide effective leadership, innovation of curricular practices will not be successful (Swihart, 1971).

Change in Teaching Practices. If a new program is to be implemented well, it must become "a natural part of teachers' repertoire of teaching skills" (Guskey, 2002, p. 388). It must, in essence become a habit. Implementing the NGSS will demand significant changes for teachers and will require purposeful design of learning opportunities for teachers. Penuel, Harris, and DeBarger (2015) forewarn that teachers and leaders will have to "learn on the fly as they invent new strategies to address challenges that arise with implementation" (p. 49).

With the NGSS, teachers will need to interconnect the three dimensions of disciplinary core ideas (DCIs), scientific and engineering practices, and crosscutting concepts. They will also need to recognize learning progressions, which identify how the skills are demonstrated with increasing proficiency. The science concepts in the NGSS build coherently from K-12. Next, teachers need to include engineering design. By incorporating engineering practices with the DCIs, students build a richer network of connected ideas that "serves as a conceptual tool for explaining phenomena, solving problems, and making decisions" (Krajcik, et al., 2014, p. 159). Teachers will also need to address the nature of science. While this was not addressed in the *Framework*, after feedback from the states and public, it was included in the original NGSS. Finally, teachers need to coordinate science with the Common Core State Standards for ELA/literacy and mathematics (Bybee, 2014). This can be done with the nonfiction reading and writing and doing data analysis and graphing.

Change in Learning Outcomes. In Guskey's model, learning outcomes can include not only cognitive and achievement indices, but also the wide range of student behavior and attitudes (Guskey, 2002). Guskey's model suggests that a change in attitudes and beliefs of teachers is unlikely in the absence of positive changes in students' learning (Guskey, 2002). Much research supports this notion. Studies have shown that teachers will adopt a new practice when they see positive changes in their students, such as changes in student flexibility (Star et al., 2015), increased student engagement and achievement (Andersson & Reimers, 2010; Pintrich, 2003), student learning (Soto Kile, 2006), reduced disruptive behaviors (Bradshaw, Mitchell, & Leaf, 2010), or positive emotions (Polikoff, Le, Danielson, Sinatra, & Marsh, 2017).

Change in Beliefs and Attitudes. Attitudes and beliefs about teaching are largely derived from classroom experience. If a teacher has been unsuccessful in reaching a particular subgroup, he or she may feel these students are incapable of academic excellence. However, if a new instructional strategy helps the subgroup of students learn, his or her beliefs about those students are likely to change. Evidence in the classroom generally precedes a significant change in teacher's attitudes or beliefs (Guskey, 2002).

Emotions and feelings can influence whether a change succeeds or fails. Organizations, especially educational organizations, move back and forth from change to stability. Employee emotions at different levels can impact their behavior during the change process, and therefore both positive and negative emotions should be seen as "continual and mutually informative" (Klarner, By, & Diefenbach, 2011, p. 333). During a curriculum change process, teachers may feel the requirements are daunting and have problems making sense of the change (Tong, 2010). Therefore, careful planning and organization must be done first (Wong, 2001). Moreover, even with all of the planning and preparation to successfully go through a change, employees will still need supports as they adapt through both positive and negative emotions. Employee emotions during a change should be seen as feedback, and used to make decisions about additional supports needed.

Fullan's Educational Change Model

Fullan's (2007) educational change model also comprises three phases that form the change cycle. It can be compared to Lewin's model in that the first phase, initiation, is the point of unfreezing; the second phase, implementation, is the change, and the third phase, institutionalization, is the point of refreezing. Phase one, initiation, consists of the process that precedes the decision to change a practice within a school system. Innovations get initiated from many different sources and for different reasons. Phase two, implementation, involves the first experiences of attempting to put an idea or reform into practice. Phase three, institutionalization, or continuation, refers to whether the change gets built in as an ongoing part of the system (Fullan, 2007). An overview of the change process can be seen in the following diagram.

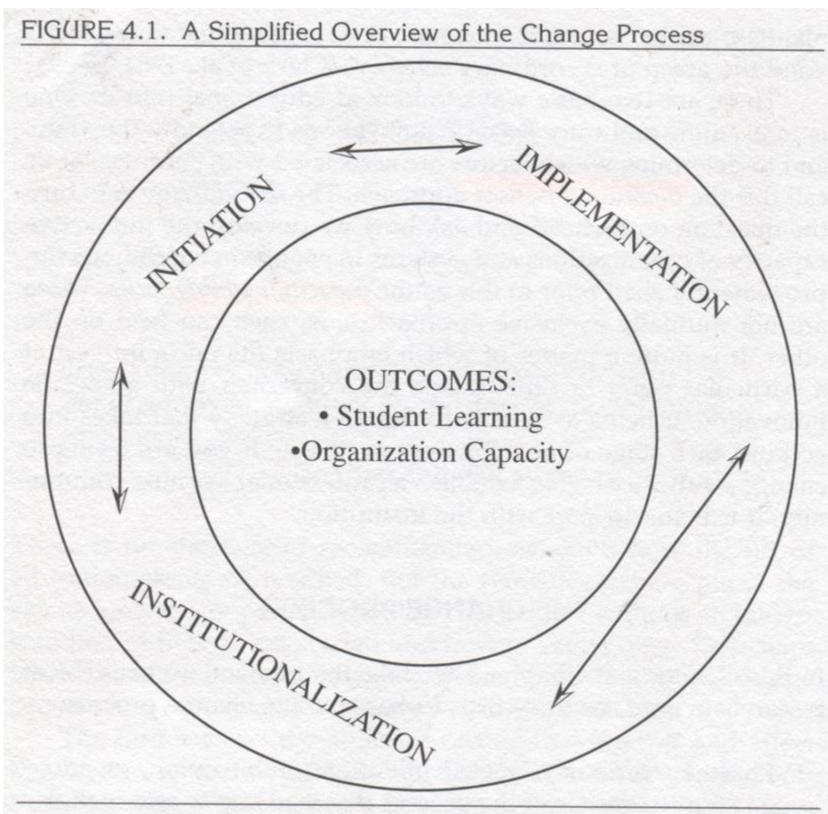

Figure 4: Fullan's (2007) Educational Change Model (p. 66).

Initiation. Initiation is the first phase of the change cycle. (Fullan, 2007). There are many educational innovations out there, and there are different factors that influence whether a change is initiated. Change can be driven solely from the top. But, for continued success, change should come from within each employee. Kotter and Cohen (2002) were strong proponents of getting emotional "buy in".

Implementation. Implementation involves the process of putting an idea, program or set of activities and structures into practice. It is the means of accomplishing desired objectives. Overall, effective strategies for improvement require an understanding of the process, and not simply following a list of steps. Fullan (2007) suggests "good change is hard work" (p. 92) and substantial reform requires persistently working on multilevel meaning across the system over time.

Institutionalization. Institutionalization, or continuation, is the final phase of the change process. The continuation of innovations depends on whether or not the change gets embedded or built into the structure through policy, budget, timetable, etc.; has generated a critical mass of administrators and teachers who are skilled in and committed to the change; and has established procedures for continuing assistance, especially relative to supporting teachers and administrators. Fullan's model is influenced by student learning and organizational capacity.

The three change models summarized above reinforce the notion that change entails a process. Whether it is Lewin's (1947) "Unfreeze→Change→Refreeze" or Guskey's (1985) "New Model of Teacher Change" or Fullan's (2007) "Educational Change Theory", each model follows a predictable flow, even if some of the components are interacting. As organizational change authors have asserted, change is messy (Fullan, 2007; Burke, 2014), but if leaders communicate the change clearly, empower action, give the necessary supports, and celebrate short-term wins, the change has a greater chance of being successful.

Critics of The Theory

Wilson & Peterson (2006) warn against rejecting the behaviorist theories of learning. They posit, "students can learn while they absorb new information [passively]…activity does not mean that learning is taking place" (p. 3). Still, Gosser, Kampmeier, & Varma-Nelson (2010) found that "lecture can be reduced without compromising content if the time is spent on activities that promote active engagement of the students with the subject matter and with each other" (p. 278).

Some research shows that teacher-directed instruction, in the form of questioning students, can positively impact student outcomes, especially for students with emotional behavioral disorders (MacSuga-Gage & Simonsen, 2015). When teachers question students, and give students opportunities to respond with follow-up feedback, it improves active engagement of all students (Simonsen, Fairbanks, Briesch, Myers, & Sugai, 2008).

Learner-centered teaching still allows for teacher-directed questioning techniques, but the role transforms to that of a facilitator. Student peers are equally encouraged to ask and provide feedback to questions through a Socratic seminar. Learner-centered teaching and experiential learning has been shown to be an effective method for instilling the necessary skills students will need to be competitive in the 21st century.

Summary

This chapter outlined the change process of science standards leading up to the Next Generation Science Standards. While the NGSS is still in the process of being adopted by states, there will continue to be changes in teaching practices, materials, and assessments. Planned change is a process that follows steps, including unfreezing/initiation, changing/implementation, and refreezing/institutionalization. In the unfreezing/initiation step, professional development and training, the first step in Guskey's (1985) model of teacher change, is vital for the change effort to be successful. In the changing/implementation step, teachers will be changing their practice, the second step in Guskey's model, to align to the goals of the NGSS. During this step, there should also be changes in student outcomes, the third step in Guskey's model, based on the new standards and new student-centered teaching practices. Finally, during the refreeze/institutionalization step, teachers will have changes in their attitudes or beliefs, which is the final step in Guskey's model, in response to their student outcomes.

Chapter 3: Research Design and Methodology

This purpose of this qualitative case study was to explore the changes in practice of fourth and fifth grade science teachers, who went through the implementation of an NGSS-aligned, learner-centered science curriculum, KnowAtom™, in an urban school district in Massachusetts. The question the researcher explored is “How have fourth and fifth grade science teachers had to change their teaching practices to implement a new experiential learning curriculum in their classroom to meet the demands of the NGSS?”

This chapter will present the design for this instrumental case study of change in teaching practices as a result of the implementation of this curriculum in one urban school district in New England. The researcher selected an instrumental case study design because of the nature of the research problem and the question being asked (Merriam, 1998, p. 41; Rosenberg & Yates, 2007).

Qualitative Research

A qualitative method was used to extract the changes in practice by the fourth and fifth grade science teachers. Qualitative research involves the collection, analysis, and interpretation of data that are not easily reduced to numbers (Anderson, 2010).

The researcher’s exploration fell under a constructivist-interpretivist paradigm, which forms a foundation, or “anchor” (Ponterotto, 2005, p. 129) for qualitative research methods. Constructivists (or interpretivists) advocate a hermeneutical approach and hold that reality is constructed rather than discovered (Merriam, 1998; Ponterotto, 2005; Stake, 1995). Only through the interaction between the researcher and participant can deeper meaning be uncovered (Ponterotto, 2005).

Anderson (1996) defined constructivism as an interactive process during which teachers and learners work together to create new ideas in their mutual attempt to connect previous understandings to new knowledge. Constructivists promote giving students purposeful activities in which they can construct their own knowledge.

Qualitative case study methodology facilitates the exploration of a phenomenon within its context using a variety of data sources (Baxter & Jack, 2008; Yin, 1984). There are many approaches to qualitative research, the most common being narrative research, phenomenological research, grounded theory research, ethnography, and case study research. While they all tend to follow the basic process of research (Creswell, 2013), the best approach is based on what is right for the researcher's problem.

Case study was chosen as the approach for this study because the investigator wanted to explore "a real-life, contemporary bounded system (or case) …through detailed, in-depth data collection involving multiple sources of information" (Creswell, 2013, p. 97). Case study research is a flexible approach to research design that "focuses on a particular case- whether an individual, a collective, or a phenomenon of interest" (Rosenberg & Yates, 2007, p. 447). Stake (1995) posited, "the purpose of a case report is not to represent the world, but to represent the case" (p. 460). Yin (2003) advised to consider a case study when the focus of the study is to answer a "how" or "why" question, which is the type of question this study is answering.

Three seminal authors are often quoted when discussing case study: Yin, Stake, and Merriam. While some believe Yin's approach to case study is that of a positivist (Brown, 2008; Yazan, 2015), other researchers believe both Stake (1995) and Yin (2003) base their approach to case study on a constructivist paradigm (Baxter & Jack, 2008). Constructivism assumes multiple, equally valid realities, which can be co-constructed through the interactive researcher-participant dialogue. Merriam (1998), was also oriented toward constructivism (Yazan, 2015, p. 137). Her approach to case study was to focus on the process of inquiry rather than the outcome of the research (Brown, 2008). She, along with other researchers (Creswell, 2013; Miles & Huberman, 1994; Stake, 1995; Yin, 2003), maintain that a defining characteristic of case study is to delimit the object of study- the case- by defining the boundaries the researcher can "fence in" (Merriam, 1998, p. 27).

According to Merriam (1998), "innovative programs and practices are often the focus of case studies in education." (p. 38). There are many types of case studies; however, since the researcher was interviewing and observing teachers to explore the changes in teaching practice using an innovative standards-aligned program, KnowAtom™, an instrumental case study was suitable. When case study is instrumental to understanding something else, it is called an "instrumental case study" (Stake, 1995, p. 3). Instrumental case studies provide insight into an issue or helps redraw a generalization. The case is of secondary interest and facilitates the researcher's understanding of something else (Stake, 1995). In an instrumental case study, a small group of subjects are selected in order to examine a certain pattern of behavior (Zainal, 2007). The use of case study in this situation was to understand something other than the teacher or the curriculum; it was to evaluate changes in practice with the KnowAtom™ NGSS-aligned curriculum.

Case study was a fitting qualitative approach to address the research question because the goal of the research was not to make broad generalizations, but to focus on the changes required of teachers using a specific science curriculum. Additionally, case study enabled the researcher to explore a phenomenon within its context using a variety of data sources (Yin, 2013). Having multiple sources can promote the reliability of the case study evidence by the "development of converging lines of inquiry, a process of triangulation" (Yin, 2013, p. 115).

Participants

The participants in this study were isolated to fourth or fifth grade science teachers, who had implemented the KnowAtom™ curriculum for at least two years. The researcher chose to exclude the perspectives of first year implementers because change is an ongoing process, not a short-term event(Hall & Hord, 2015), and requires ongoing support, resources, and time. Expecting teachers to understand the changes in practices within the first year of implementation seemed unrealistic. Fullan (2007) proposed the implementation phase usually takes “two-three years of use” (p. 65). The researcher felt it was important to have realistic expectations about the time needed to see which changes were solidified in practice.

The first step toward protecting the participants was to go through the university’s institutional review board (IRB) process (Appendix A). Once the researcher was granted permission by the university, she then had to go through the school district’s own IRB process, permitting the researcher to collect data in the district. The researcher used a “purposeful” (Merriam, 2002, p. 15), criterion-based convenience sampling method to identify the study’s participants. The teacher participants were selected and recruited (Appendix B) through purposeful sampling based on being the best person to help the researcher understand the particular phenomenon of changing teaching practices. Creswell (2013) mentioned criterion sampling works well when all individuals studied represent people who have experienced the phenomenon. Creswell (2013) presented three considerations of the purposeful sampling strategy: deciding the participants or sites, selecting the sampling strategy, and determining the sample size. Merriam (2009) said there was no [correct] answer to how many is a good sample size (p. 80); but some researchers suggest to have as many participants as necessary until “theoretical saturation” (Morse, 1995; Sandelowski, 1995) is reached. Romney, Weller, and

Batchelder (1986) found that as few as four participants can be "quite sufficient in providing complete and accurate information within a particular cultural context, as long as the participants possess a certain degree of expertise about the domain of inquiry", which has been called "cultural competence" (Guest, Bunce, & Johnson, 2006, p.74).

Seven fourth and fifth grade science teachers, who met the study's sampling criteria, were interviewed after the researcher received the signed teacher consent (Appendix C), but one participant was dropped from the study after the researcher learned the participant was just completing the first year of implementation. The researcher followed an interview protocol (Appendix D) when interviewing all participants. Additionally, one school administrator in the district was recruited (Appendix E) and, after signing a consent, interviewed using an interview protocol (Appendix F) in order to hear the unique perspective on the changes in both teaching practices and student outcomes the administrator had personally observed. This administrator also provided specific school data the district had collected on its schools. Finally, an employee from KnowAtom™, the science curriculum being used in the district, was recruited (Appendix G) and interviewed with an interview protocol (Appendix H) in order to explore the alignment of the curriculum to the NGSS. Furthermore, this particular interview helped the researcher gain a broader grasp of the professional development the company provides as well as understanding what the participant had witnessed in regard to changes in teaching practices and student outcomes.

In this case, the school district had been in the process of implementing the KnowAtom™ science curriculum. The fourth and fifth grade science teachers were especially affected since their students have to take the Massachusetts Comprehensive Assessment System (MCAS) in science for the first time in fifth grade. This experience made them ideal interviewees. The school district in this study showed strong growth in its MCAS scores for the schools that had implemented the KnowAtom™ science curriculum. The KnowAtom™ curriculum pushed teachers to assume the role of classroom facilitators, which was a change in teaching practice for the teachers. This change resulted in positive student learning outcomes which subsequently, changed the teachers' attitudes and beliefs about the curriculum, their teaching practices, and their students' capabilities (Guskey, 1985).

Procedures

Data Collection

Qualitative data collection consists of collecting data from interviews using general, emerging questions to permit the participant to generate responses. Data was gathered through direct observation, semi-structured interviews, and documents, such as research journals and analytic memos, news or media articles, archival records from the Massachusetts Department of Elementary and Secondary Education, and audiovisual material (Creswell, 2013; Yin, 2013).

Using documents can help corroborate and boost evidence from other sources, as well as make inferences. However, it should be noted that documents are often "written for some specific purpose and should not be seen as the absolute truth" (Yin, 2013, p. 105), so the researcher was careful to determine the conditions under which the document was produced as well as the document's accuracy.

Case study allows for the use of multiple data sources, including quantitative survey data, which makes it unique among other qualitative approaches. Each of the data sources, including qualitative and quantitative, contributes to the researcher's understanding of the whole phenomenon (Baxter & Jack, 2008, p. 554), and using them in combination will strengthen a case study.

When interviewing for a case study design, there are different types of interviews. Rubin and Rubin (2012) recommend “responsive interviewing” (p. 72) to allow well-informed interviewees to provide important insights into the event (Yin, 2013). Seidman (2013) recommends doing three interviews with each participant because “people’s behavior becomes meaningful and understandable when placed in the context of their lives and the lives of others around them” (p. 16). The researcher did an adapted version of Seidman’s recommendation. The first interview was conducted through an introductory email in which the participant responded with their agreement to participate in the study and answered a few background questions. The second interview was conducted in person at the study site and included questions that aligned to the conceptual framework and the research questions. The third and final interview was a follow-up email and/or phone conversation to verify that the transcripts depicted an accurate portrayal of the in-person interview. The third interview also gave participants the opportunity to add information or to amend their words or phrases to provide further clarity about meaning.

Phase I. In the first phase of data collection, the researcher gained approval from her university’s Institutional Review board, then submitted a study proposal to the school districts Institutional Review Board for approval. Once the study was approved at the district level, research began. First, potential participants were sent an initial email to specify the study’s criteria. Secondly, potential participants, who met the criteria, were then invited to participate in the study, asked some background questions, and given the information on how their information would be kept confidential. Lastly, the participants were asked to read and sign an informed consent release, explaining the study’s objectives as well as the process of protecting their identities. If the potential participant agreed with the nature of consent, they then signed the release, officially becoming study participants.

Phase II. In the second phase of data collection, the participants engaged in two interviews. The initial interview was in person and lasted between twenty and fifty minutes and was conducted after the consent form was signed. During the audio-recorded interview, the researcher kept a reflective journal and jotted field notes, which helped the researcher focus on active listening and minimized researcher bias. Interviews were professionally transcribed by a third-party within two days, and were shared using an alias for the interviewee. After the researcher read through the transcription and made edits using the audio-recording, the transcribed interview was then shared with the participants.

The final interview occurred after the participant had read the transcription. During this interview, the participant verified all details and had the opportunity to add any additional details or clarification statements. The second interview occurred either in-person, by email, or by telephone for the convenience of the participant.

Phase III. In the third phase of data collection, the researcher read through the data several times, writing margin notes and hunches. Open coding was used to initially categorize the data into its major categories of information (Creswell, 2013). Rubin and Rubin (2012) recommend to find concepts and themes that speak to the research question. They advise to code the nouns and noun phrases most relevant to the study. Axial coding was then used to relate the codes to each other through inductive reasoning. Seidman (2013) contends the data must be reduced inductively, so researchers will have to make judgment calls. Miles, Huberman, & Saldana (2014) suggest conceptual frameworks and the research questions as the best defense against data overload. Using this suggestion, the data was reassembled to identify connections, relationships, and links back to the initial research questions. By comparing the information to other interviews and other sources, the researcher certified the validity of the story.

Managing Data. Throughout the study, data sources were managed using a personal computer that is password protected. Data files were encrypted and the computer kept locked when it was not in use by the researcher.

Data Analysis

According to Creswell (2013), there are six major steps in the process of analyzing data. First, the researcher has to collect the data. To begin the process of data collection, the researcher collects the text and images through interviews, observations, and documents. Second, the researcher prepares the data for analysis by transcribing the data from the interviews. To begin working with the material, the researcher first makes it accessible by organizing it (Seidman, 2013). Third, the researcher reads through the data to obtain a general sense of the material. This initial reading may help the researcher extract initial themes. Because of the various types and amounts of data, it is helpful for researchers to use a Computer Aided Qualitative Data Analysis Software (CAQDAS) program, like NVivo, to help organize and make sense of the data. "Using a database improves the reliability of the case study as it enables the researcher to track and organize data sources… for easy retrieval at a later date" (Baxter & Jack, 2008, p. 555). Additionally, data analysis software can create data displays, which can help a researcher better understand connections. Fourth, the researcher codes the data by locating in vivo text segments and assigning a code to them. Fifth, the researcher codes the text for themes to be used. Finally, in the sixth step, the researcher codes the text for description to be used.

Criteria for Quality Qualitative Research

Qualitative research embraces multiple standards of quality, which include ethical considerations, credibility, transferability, and self-reflexivity and transparency. Additionally, because a case study is a bounded system, there will be limitations to the study. These standards and limitations will be discussed in this section.

Ethical Considerations

A qualitative researcher has an obligation to protect the institutions and participants involved in a study. Qualitative researchers research private lives and publish their findings in a public arena. This study's interview protocols, as recommended by Qu & Dumay (2011), were developed to assure the interviewee's personal information was kept confidential. The protocols also served to inform participants about the possible harm or inconvenience to them for their participation, giving them the opportunity to opt out of the study for any reason. Pseudonyms were used when discussing the school district and the participants themselves. Data were stored behind password-protected files on the researcher's computer and will be destroyed two years after the study has been completed, while audio files will be destroyed after six months of study completion.

Credibility

In qualitative research, credibility corresponds to internal validity in quantitative approaches and refers to the idea of internal consistency (Morrow, 2005). The research question that was the focus of this study is "How have fourth and fifth grade science teachers changed their teaching practices to implement KnowAtom™, a learner-centered, NGSS-aligned curriculum in their classrooms?" The conceptual framework that provided the lens for this study was Guskey's four-step Model of Teacher Change.

The case was isolated, or bounded, to fourth and fifth grade science teachers, who have implemented the KnowAtom™ curriculum in their classrooms for at least two years. An instrumental case study approach was used and data was collected through documentation review, in-depth interviews, and direct observations. The researcher audio recorded all interviews and had them transcribed by a third-party transcription service within two days. The transcripts were uploaded into NVivo software, which helped organize and analyze the data. Themes were extracted inductively and viewed through the framework for the study. Finally, the researcher kept a research journal of reflections, timelines, notes, and jots during recorded interviews. Analytic memos were written throughout the interview process, which took place over three days.

The researcher did at least one in-depth, in-person interview with each participant, using an adaptation of Seidman's (2013) three-interview recommendation (p. 17-19). Seidman (2013) recommended to conduct three interviews, first exploring the life and teaching history of the participant. The researcher asked these background questions in the initial email contact. Seidman (2013) wrote, "Because we understand that meaning is best achieved in context, we take the time to establish a contextual history for the participants' current experience" (p. 19). Seidman recommended for the second interview, in this case the in-person interview, to explore the details of the experience which, in this case, was on the participants' interactions with the students and the curriculum and the changes they have made in their teaching practice. The final interview, according to Seidman (2013) is to be a reflection on the meaning. In this study, the reflection was on the connection between the change experience and what the future holds for the participant's teaching style and was also done during the in-person interview. This detailed engagement helped the researcher to become more familiar with the participants, providing a deeper understanding of the participants' experiences.

The researcher also did direct observations of the participants to provide context for the changes in practice. Descriptive notes, as well as reflective notes (i.e. what was seen, heard, experienced, and thought about) from the observation were written up immediately following the observation to ensure accuracy of recall.

Testing results from the school and the Massachusetts Department of Education website were used to support the case with quantitative results of the change. After collecting multiple data sources in the form of documents, direct observations, and in-depth interviews, the researcher used triangulation to examine the consistency of the findings. Stake (1995) recommended using triangulation, or “multiple perceptions to clarify meaning, verifying the repeatability of an observation or its interpretation” (p. 454). Yin (2013) suggested using multiple sources of evidence, create a case study database, and maintain a chain of evidence to ensure a high-quality case study. The researcher used the pieces of data to form data categories and find patterns in the data, which ensured validity (Yazan, 2015).

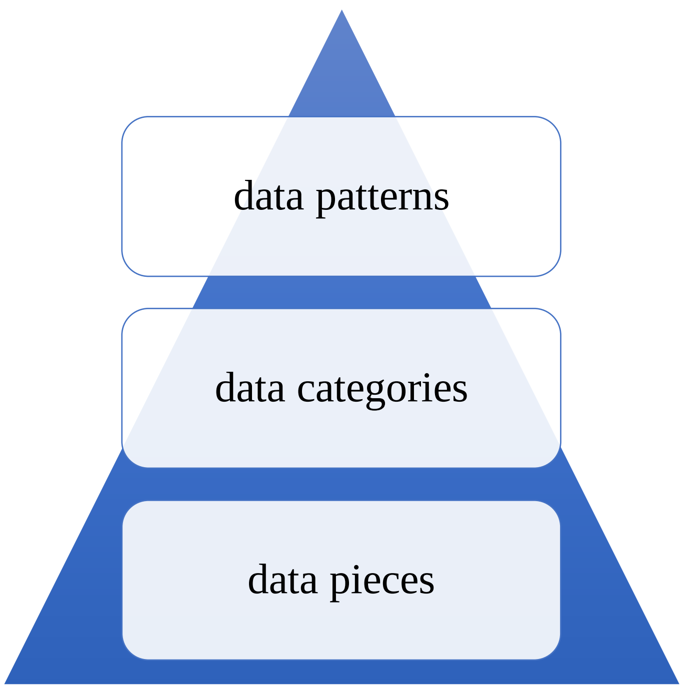

Figure 5. Data triangle.

To enhance credibility, the researcher used peer debriefing and member checking. Initial findings were discussed with another science educator familiar with KnowAtom™ and the

NGSS (Lincoln & Guba, 1985; Rocco & Hatcher, 2011) to help uncover any hidden biases or assumptions. Also, the participants were provided a transcript of the interview and allowed to clear up any perceived misinterpretations. This also allowed the participants an opportunity to volunteer additional information that may have been relevant to the study.

Transferability

Transferability was achieved by the researcher providing sufficient information in the form of “thick description” (Morrow, 2005, p. 252; Merriam, 1998) and clarity of presentation. Getting the information in the form of rich, descriptive stories from the participants helped capture the complexities of real-life situations that may not have been captured through experimental or survey research (Zainal, 2007). Furthermore, “richly descriptive” (Merriam & Tisdell, 2016, p. 17) stories allow the reader to make his or her own interpretation of the phenomenon under study.

Self-reflexivity and Transparency

Self-reflexivity and transparency (openness and honesty) are essential components of qualitative research (Fossey, Harvey, McDermott, & Davidson, 2002). The researcher is situated within the research and is telling the stories of others. Therefore, to ensure transparency, a description of the author’s background, identity and bias, and philosophy will now be discussed.

Author Background. My entry into teaching happened when I chose to make a career change in my thirties and teach in a private school. That experience transformed my life. I realized the strong passion I had for seeing children learn and grow. The experience was so rewarding, it prompted me to go back to school and get my master’s degree in education and subsequently, pursue my doctorate in education.

Over the past decade, I have enjoyed a diverse teaching experience, teaching every core subject across multiple grade levels. I have taught in private, charter, and public schools, in both urban and suburban districts, and in the United States as well as internationally. Additionally, I have served in school administrative positions as a Curriculum Coordinator in a private and charter school and as an Academic Director of a K-12 International Baccalaureate school in Central America. Most of my teaching experience has been as a middle school science teacher. With my undergraduate degree in science and information technology, incorporating STEM into my classrooms was a natural step. Seeing children learn by participating in hands-on investigations and activities in groups has made me a strong social constructivist.

Identity and Bias. As a scholar-practitioner, it is essential for me to be introspective of my identity and positionality. I am a white, heterosexual, married, Christian, female, who is also a mother, grandmother, scholar-practitioner, and teacher. These parts of my identity in themselves contribute to biases. It is still possible for me to produce knowledge that is valid as long as I include an acknowledgment of my positionality (Maher & Tetreault, 1993, p. 118). "Researchers within a culture as well as those outside it both face opportunities and challenges" (Banks, 2006, p. 775). As a researcher, I was an outsider looking in, but worked with my participants to mutually construct their stories. As a science teacher, who implemented the KnowAtom™ curriculum in my own science classes, I felt I could lend a sympathetic ear to the stories of my participants.

As a proponent of social constructivism, I believe power should be shared and knowledge should be mutually constructed between all parties involved. Each person has a unique perspective to give. My views align with Takacs (2002) when he wrote, "To work toward a just world- a world where all have equal access to opportunity- means, as a start, opening up heart and mind to the perspectives of others" (p. 169). This is the foundation of my research interest. The goal of this researcher, like other scholar-practitioners, was to "generate new knowledge and improve practice" (Wasserman & Kram, 2009, p. 12).

Limitations

This qualitative case study was limited to fourth and fifth grade science teachers, who had implemented KnowAtom™ in their classrooms for at least two consecutive years. The sample size included six teacher participants, one district administrator, and a KnowAtom™ cofounder. The study's setting was an urban school district in Massachusetts.

Conclusion

Case studies are a useful type of qualitative research for refining theories and suggesting complexities for further investigations, as well as helping to establish the limits of generalizability (Stake, 1995). There are many types of case studies, and the type of case study chosen depends on the type of question the researcher is asking. Although the terms reliability and validity traditionally have been associated with quantitative research, they are increasingly being seen as important concepts for qualitative research, as well. Researchers can increase reliability and validity by using multiple sources of evidence, creating a case study database, and maintaining a chain of evidence to ensure a high-quality case study (Yin, 2013).

Before researchers present their findings, they must address the validity and reliability of the research. When representing the case, the qualitative researcher must present an accurate representation of the phenomena under study. One way to increase validity is through triangulation, which is using multiple perspectives and multiple methods to study the same phenomenon. By using a combination of methods in a study of a phenomenon, any bias in a particular data source, investigator, or method, would be neutralized (Johnstone, 2007).

Additionally, the researcher should present competing conclusions. The researcher's role is to present the case and let the reader make their own inferences. Researchers must remain transparent in the way they present the evidence to reflect trustworthiness principles, particularly reflexivity and trackability. Every attempt was made to keep the investigation transparent so readers can form their own conclusions.

Chapter 4: Findings

Introduction

The primary goal of this research was to examine the impact of a NGSS-based curriculum on fourth and fifth grade science teaching practices. The researcher's intent was to gain an understanding of what changes occurred in order to align those teaching practices with the demands of the NGSS, which specify expectations of student learning outcomes. In addition to interviewing science teachers, the researcher also interviewed both a school administrator and the co-founder of KnowAtom™, not only to give voice to additional stakeholders' perceptions of the program, but also to add additional data that could deepen the analysis through data triangulation.

Through an in-depth analysis of all available data, the researcher discovered the teachers shared common initial feelings regarding change, as well as similar changes in their teaching practices and new student outcomes. The themes that emerged were tied back to the research questions and the theoretical framework. The following research questions guided the study's exploration of the impact of the implementation of the KnowAtom™ curriculum on science teaching practices:

1. What were the participants' initial feelings about implementing the KnowAtom™ curriculum (RQ1)?
2. What professional development opportunities were provided to the participants (RQ2)?
3. How did the participants shift their teaching practices to meet the demands of the NGSS (RQ3)?
4. What changes did the participants notice in learning outcomes for their students (RQ4)?

5. How did the teachers' attitudes or beliefs change after implementing the KnowAtom™ science curriculum (RQ5)?

After obtaining the district email addresses of all fourth and fifth grade science teachers using KnowAtom™ in the study district, the researcher sent an introductory email (Appendix B) to the teachers outlining the study's criteria and requesting their participation in this study. Out of a total of thirty-eight fourth or fifth grade science teachers, seven teachers from five different schools responded noting their interest in participation. Only those teachers who opted into the study were asked to answer the few demographic questions, which were included on the introductory email.

Interviews were conducted over three days. One candidate was eliminated from the study because he did not meet the study's criteria of using the KnowAtom™ curriculum for two consecutive years. In order to ensure the reliability of the transcriptions, participants were given the opportunity to read through the transcriptions and make edits or additions. Interview recordings were transcribed within one day using a third-party service and sent to the participants within twenty-four hours after transcription. The researcher followed up with participants within one week to verify the accuracy of the transcription.

This chapter begins with an overview of the study setting, followed by a description of the participants, including the teachers, the administrator, and a KnowAtom™ cofounder. A brief section describing the background behind the program implementation will then be presented. The chapter will conclude with the study findings, organized by each of the research questions.

Setting

This study took place in an urban public school district in the Northeastern section of the United States. At the time of the study, the school district had twenty-six schools, including a combination of fourteen elementary and middle schools that include fourth and fifth grades. The total student population in the district was almost 14,000. Almost three quarters of the district's students, seventy-one percent, were English Language Learners in 2017-2018. At that time, sixty-four percent of the students were classified as economically disadvantaged, with over eighty-two percent of students reported as high needs, meaning students at risk of educational failure or otherwise in need of special assistance and support. The in-person interviews were conducted at a location of the participants' choosing to increase comfort and convenience. For teacher-participants, the interviews occurred during a planning period or after school.

Participants

The participants included six fourth and fifth grade science teachers, one district administrator, and the co-founder of KnowAtom™, Francis Vigeant, who agreed to be identified in this study. The teacher participants had been teaching on average for 12.7 years, with individual teacher's experience ranging from three to twenty-five years. The six science teacher participants consisted of five female teachers and one male teacher. All the teachers studied education in college and five had earned master's degrees, with the sixth currently pursuing her master's degree. The teachers and the administrator were given pseudonyms to protect their identities.

KnowAtom™ Representative

Francis Vigeant, a co-founder of KnowAtom™, grew up in a single-parent household in an urban community. He attended an urban public school and eventually became a teacher of mathematics and science in an urban public school. He reported that while teaching in an urban district, he felt limited by the curriculum and lack of resources, in addition to the general challenges faced in urban communities. This dissatisfaction with the status quo led to KnowAtom™ being founded.

According to Francis, the primary focus of the KnowAtom™ curriculum is to instill higher order thinking skills in students. He noted his strong belief that science learning is best facilitated through hands-on, inquiry-based activities. Francis commented, “We don’t need even half of our students to be scientists or engineers, but we need all of our students to think critically, particularly creatively, evaluatively, and analytically” (F. Vigeant, personal communication, June 1, 2018).

District Administrator

The district administrator, Ms. Taylor, reported working in education for forty years, serving over half of that time as a school administrator in some facet. For five years preceding the study, she had served as a district administrator in the study district, and as an advocate for adopting and implementing the KnowAtom™ curriculum in the district. Before becoming an administrator, Ms. Taylor taught every grade level from kindergarten through twelfth grade as a special education teacher. She initially began her undergraduate degree in early childhood education but, after working for a while in a preschool, she quickly shifted her focus to special education, where she felt a deep affinity. She graduated with an elementary education and special education double major.

When teaching, Ms. Taylor described finding joy in helping a child learn to read for the first time. She also recalled the frustration she felt when wanting a child to gain proficiency, but not having access to appropriate resources and teaching materials. It was this experience as a former teacher that pushed her to be creative in finding resources for those under her leadership.

Teacher Participants

The teacher-participants had all been teaching the KnowAtom^{TM} curriculum for at least two years. They ranged from being relatively new to the teaching profession to having taught for twenty-five years.

Gigi. Gigi was the first teacher-participant interviewed. She was a young teacher in her third year of teaching fifth grade. Gigi's undergraduate major was elementary education with a science focus, and she is now pursuing a master's degree in curriculum and instruction. Gigi felt her inquiry-based science courses in college helped prepare her for teaching. She remarked, "We had three science education courses, which were superb. We learned science the way students should be taught science. So we actually did the activities which were all hands-on and inquiry-based" (personal communication, June 14, 2018). She also shared that she had worked to enhance her science knowledge by doing a summer program at a university, where she took two field ecology courses, and even spent a summer co-managing a community garden.

Lily. Lily, the second teacher-participant, did her undergraduate degree in business, but earned her master's degree in education. She was an eighteen-year teaching veteran, mostly as a third and fourth grade general education teacher. To prepare herself for teaching fourth grade science, she reported completing background reading on the curriculum, while drawing upon her general education teaching background. She stated that she enjoys working with the students as each day teaching is a different experience. While she observed that some of her students struggle with controlling their behavior through the school day, she shared her observation that they struggle less in science because of the hands-on curriculum.

Abbie. The third participant, Abbie, was a seasoned educator of almost twenty years. She earned her bachelor's degree in elementary education, initially teaching for three years before leaving to pursue a master's degree in business administration (MBA). After the MBA, she worked in the business sector for several years until returning to teaching profession sixteen years ago. She shared that she loved her job. In terms of content areas, Abbie had been an English language arts (ELA)/literacy teacher for years before she was moved mid-year into a science teaching position a couple of years ago. While she noted that the move was initially stressful, she has since embraced it and finds value using her ELA/literacy background to help her science students make cross-curricular connections.

The majority of Abbie's fifth grade students were English language learners (ELLs) and she reported that she devotes herself to making the science material accessible to them and is gratified to watch them grow intellectually. Given the large number of ELLs, she conveyed that the pressure on standardized test scores was the most challenging part of her job. She also reported that her teacher preparation program, completed over two decades ago, did nothing to prepare her for science instruction (personal communication, June 14, 2018).

Sophie. Sophie, the fourth participant, stated that she had been consistently teaching fifth grade for ten years. She had completed her undergraduate degree in biology and sports education, reporting that this gave her a good background for teaching science. She earned her master's degree in elementary education.

Sophie shared that she was continually seeking ways to grow as an educator and improve her teaching. The best and most stressful aspect of teaching, according to Sophie, is making connections with the students, especially those lacking strong adult figures in their lives. She commented, "You want to be that person for the kids" (personal communication, June 14, 2018). While her college courses were not geared toward hands-on learning, she did have her science background and one class in graduate school that provided a good foundation for STEM (science, technology, engineering, and math).

Michelle. Michelle, the fifth participant, had been teaching science for four years. For the first two years of teaching, she was a science specialist for grades one through five, and had only started teaching fifth grade science two years ago. She explained teaching science for her was fulfilling as she found each day to be different and exciting.

Michelle earned her undergraduate degree in elementary education with a concentration in general science. She finished her graduate degree in moderate disabilities. Even with her special education background, she revealed that she still struggled with behavior management in the classroom, as she teaches in an inclusion classroom, including both general and special education students. She commented, “Science isn’t recognized in an IEP (Individual Education Plan), so I have full inclusion by myself”, meaning that she worked without the benefit of a co-teaching special educator or paraprofessional (personal communication, June 19, 2018).

Michelle communicated that she had gained a strong understanding of science concepts through her college courses and in her role as a science specialist. In spite of this, she disclosed that she felt college did little to prepare her to actually teach science. When she did finally go into the classroom during her third year of undergraduate studies, she and her classmates did hands-on activities using boxed kits with students, but she described this as recreational versus instructional time with students. Michelle imparted that she believed more should be done during teacher preparation programs to prepare teachers to deal with student behavior, especially in urban inclusion settings.

Luke. Luke, a twenty-five year teaching veteran currently teaching fifth grade, was an undergraduate biology major and earned his graduate degree in education. He reflected that while his undergraduate science classes were the best preparation for him becoming a science teacher, they did not prepare him for presenting hands-on activities. He disclosed that he has always taught at the middle school level, and even served as a middle school administrator for two years. Luke expressed his enjoyment in inspiring students to find answers to the questions they have. When asked about the most stressful aspect of his teaching, he revealed that it was "the additional duties placed on a teacher now in acting as not only teachers, but parent, counselor, etc." (personal communication, June 19, 2018).

Table 2

Teaching Participants

Name *	**Gender**	**Years of Teaching**	**Level of Education**	**Current Grade Teaching**
Gigi*	Female	3	Pursuing Master	5th
Lily*	Female	18	Master	4th
Abbie*	Female	16	Master	5th
Sophie*	Female	10	Master	5th
Michelle*	Female	4	Master	5th
Luke*	Male	25	Master	5th

(*Pseudonyms)

Background

This section describes the background of the KnowAtom™ program implementation in the district. Ms. Taylor, the district administrator, shared that in 2014, there was communication among school administrators about the new Massachusetts Frameworks in science would be closely aligned with the NGSS. She stated that she foresaw a need for the district to rethink its science curriculum. That same year, Ms. Taylor solicited participation in a working group from district educators. This group then volunteered to assemble on Saturdays to break down the NGSS and check the alignment with the district's curriculum at the time.

As a result of this process, Ms. Taylor shared that the Saturday group found the district had an archaic, outdated curriculum in relation to the NGSS. She also shared they realized that the manner that current curriculum materials had to be rotated, made it impossible to have a vertical articulation of scope and sequence. Furthermore, she divulged that elementary teachers had been given little direction on the science curriculum and, as there had been a hyper focus on mathematics and ELA/literacy, "science was practically non-existent below the tested grades" (personal communication, June 19, 2018).

With knowledge of the group's findings and anticipation of forthcoming changes in the state mandated testing program, Ms. Taylor requested that the working group examine and review various curriculum resources. Among those curriculum resources being reviewed was KnowAtom™. When KnowAtom™ was invited to present to the group, Ms. Taylor shared that what impressed the working group was that KnowAtom™ sent an entire team of company representatives with their classroom materials. Following the presentation and feedback from the working group, Ms. Taylor negotiated with KnowAtom™ and agreed to pilot two of the units in one school in the last few months of that school year.

The KnowAtom™ curriculum included digital resources, grade-level reading, materials for hands-on learning, and formative and summative assessments. This set the stage for creating an NGSS environment. An overview of the KnowAtom™ curriculum is depicted in the figure below.

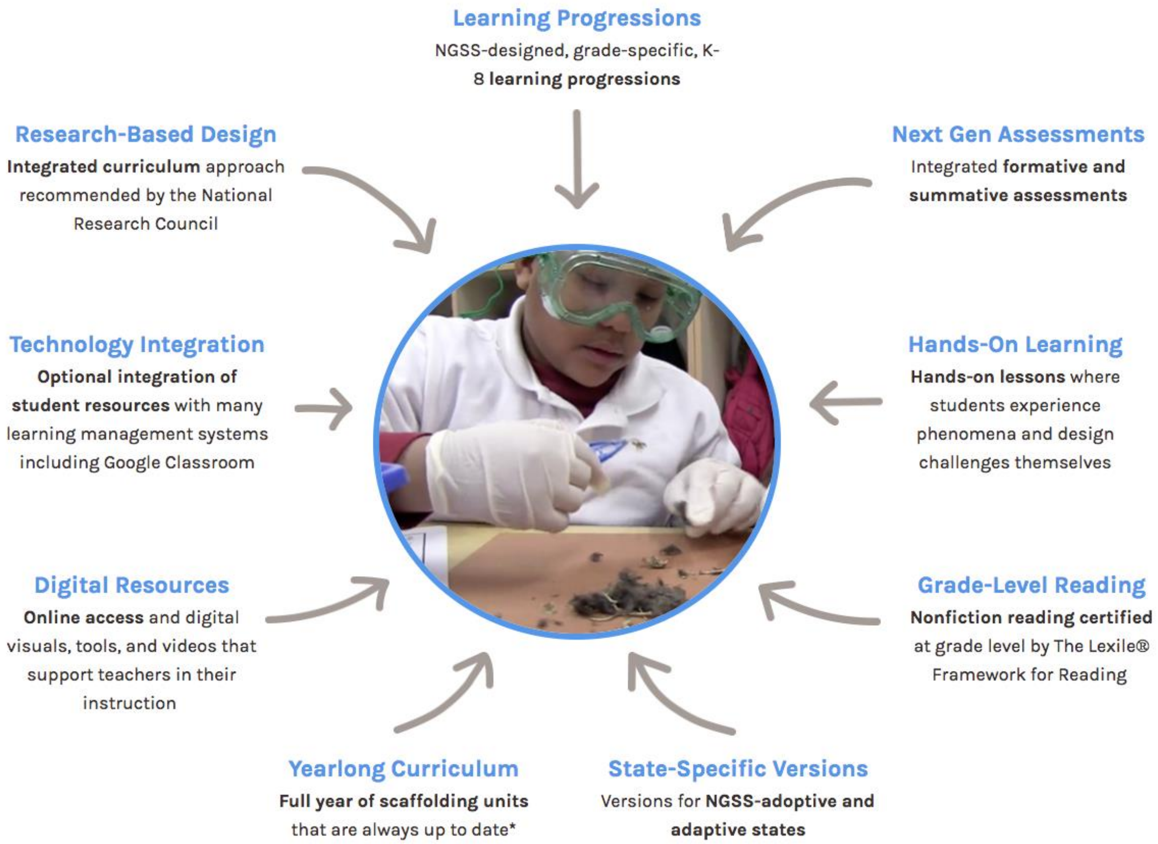

Figure 6: KnowAtom curriculum components (KnowAtom™, 2018).

During the pilot, working group members did observations of the implementation in classrooms. After these observations, they reported being impressed with the quality of the materials, the alignment with the NGSS, and the ease that the teachers applied the new materials in science lessons. Due to this feedback, as an administrator, Ms. Taylor reported exploring how to fund and make the implementation cost effective for the district. She explained that KnowAtom™ comes with some durable materials that do not have to be replaced yearly, as well as consumables that need to be replenished yearly. After speaking with the District Superintendent, it was agreed the district would provide the durables for each school and the individual schools would have to budget for the consumables, enabling a fiscally feasible investment.

Once the resource funding was in place, Ms. Taylor reiterated that while the teacher working group members were excited about the implementation, there was still a need to solicit district scale teacher buy-in, as this would entail an entirely new approach to teaching science. She shared that this innovation in teaching approach brought about a wide range of reactions from staff, which will be discussed in the following section.

Initial Feelings (RQ1)

Following the interview protocol, participants were asked to explain their initial feelings about implementing the KnowAtom™ curriculum. They reported a range of emotions including being excited on one end of the spectrum and overwhelmed on the other. Two teachers reported feeling overwhelmed because KnowAtom™ was a new curriculum and they knew it would be challenging, especially during the first year of implementation. These anxieties mirrored the researcher's concern about interviewing first-year implementers and further solidified the researcher's position on eliminating the perspectives of those in the first year of implementation. The other four teachers reported feeling excited, attributing their excitement to the consistency KnowAtom™ provided across grade levels, the inclusion of nonfiction texts, and the alignment to the NGSS. While there was initial excitement with KnowAtom™, the participants also voiced some concerns about KnowAtom's™ pedagogical approach, making interdisciplinary connections, the high reading level, the alignment to the Massachusetts standardized test, the release of responsibility, and providing additional supports for students. These will now be discussed further.

Different Approach With KnowAtom™

Gigi indicated she was initially frustrated the KnowAtom™ curriculum did not follow the typical 5 E's (Engage, Explore, Explain, Elaborate, Evaluate) instructional model she was accustomed to teaching. The 5 E's model first has students engage in making connections between past and present learning experiences, followed by the student exploring their environment and manipulating materials, building on their previous experiences. Only after the students have done some type of hands-on learning does the teacher explain the concepts and introduce formal terms and texts. On the contrary, KnowAtom™ first has students build their background knowledge by reading a nonfiction text. Next, the students engage in a Socratic discussion to deepen their understanding of the phenomenon under investigation. After the knowledge base is built, the students engage in a hands-on investigation in which they apply their understanding to a new situation.

Luke reported being concerned about what he viewed as "a rigid", standards-aligned curriculum because it was very different from what he had been doing for many years (personal communication, June 19, 2018). He confessed he had not been doing much reading or writing in his science classes and the KnowAtom™ curriculum was full of both.

Making Interdisciplinary Connections

Lily reported having initial concerns about how KnowAtom™ would connect across disciplines, but once she got into the curriculum she realized it had strong connections to the Common Core State Standards (CCSS) in both mathematics and ELA/literacy, and the curriculum's teacher resources even highlighted those connections for teachers.

High Reading Level

Lily stated she was also concerned about the high level of reading in the nonfiction text, especially with her high ELL population. She indicated she realized she would need to pre-teach the vocabulary and adapt the pacing to spend more time helping the students read and understand the text. In light of this, she admitted her struggle with the idea of putting learning in the hands of the students.

Michelle also voiced concern about the high reading level. She stated, “My kids can’t read [at grade level], so how are we going to do that?” (personal communication, June 19, 2018).

Alignment to Standardized Test

When Abbie’s school implemented KnowAtom™, it was under tremendous pressure to augment its standardized testing scores in science. While KnowAtom™ was a NGSS-designed curriculum, the state’s assessments were not yet aligned to the NGSS. Abbie conveyed her concern about how the new curriculum would prepare the students for the MCAS (Massachusetts Comprehensive Assessment System). When she expressed this concern to the KnowAtom ™ staff, they recommended that she teach the curriculum with integrity and the curriculum would still work. The KnowAtom™ belief behind this advice was that, in essence, she would be teaching critical thinking and higher order thinking skills through the content and that the students could then apply to new learning situations or contexts they would encounter on the MCAS.

Releasing Responsibility

Sophie’s articulated her initial concern with the KnowAtom™ curriculum was wrapping her head around how the program worked. She admitted she was primarily worried about giving up control of the learning to her students. She had taught using teacher-directed instruction for years and liked the way it worked. She gave students the information they would need to remember, and they wrote it down and studied it. She shared her belief that this method of teaching had worked for the previous standardized testing.

Luke also admitted his struggle with giving up control of the learning to the students. He reported that his students come to him having had very little science instruction, and therefore little background knowledge.

Students Needing Additional Support

Sophie specified her students were mostly ELLs and many were also special education students. She said she worried about finding the right instructional scaffolds aligned with KnowAtom™, such as videos or other visuals that would help her particular students be able to access the curriculum.

Michelle voiced her concern about the need for additional supports to ensure her students were going to be able to access the grade level KnowAtom™ student readers. She shared that students of the district's demographic were below grade level in reading as many of them were ELLs or transient students.

Ms. Taylor, the district administrator, stated she chose to start implementation in the middle school grades because students are tested in science in fifth grade and eighth grade and the district's science scores needed to improve. That first year, she recruited six middle schools and three fourth grades to implement the curriculum. Three years later, there were twenty schools in the district implementing KnowAtom™ and more looking to adopt it. Ms. Taylor shared that the change was a difficult adjustment for some of the teachers and they needed support throughout the implementation process, which came in the form of professional development.

Professional Development Experience (RQ2)

Whenever there is a curricular change in a district, there have to be procedures in place to ensure fidelity of the curriculum implementation. The district worked with KnowAtom™ to provide initial professional training and formed a teacher leader network for ongoing support. District Administrator, Ms. Taylor, reported viewing the new enterprise with KnowAtom™ as a partnership. The first couple of years, the district had the team from KnowAtom™ come in on a day when most of the science teachers could get together. Feedback from the teachers illuminated the fact that having fifty or sixty science educators in one room together at different stages of implementation and expertise in instructional practice, with one instructional coach trying to deliver information that was not differentiated, was not meeting the needs of the science teachers.

In response, about a year and a half ago, the district pivoted from the way it was delivering professional development. In collaboration with KnowAtom™, the district formed a network of teacher leaders known as the "Science Champions". Ms. Taylor explained that each school using KnowAtom™ was invited to nominate a Science Champion, who would meet once a month and discuss both the challenges and successes with the new curriculum. The Science Champions would work through the issues as a team and then go back to their respective schools and help the other teachers grow into the curriculum. These teacher leaders became the resource providers, instructional specialists, learning facilitators, classroom supporters, and mentors.

The science champion program was receiving such positive feedback, the district expanded its reach. At the end of last year, a fifth-grade science teacher was videotaped. The video was broken down into five segments of a lesson study that followed the KnowAtom™ sequence of lesson articulation in ten-minute chunks. The video was captioned to point out the teacher moves, and included a note taker to go with each segment so curriculum leaders in schools could use that in their subject specific professional development. The feedback provided by teachers reported how extremely helpful it was to watch authentic instruction, but even more so that the videos included the students in their urban population. These additional scaffolds provided teachers the support they needed to ensure fidelity to the curriculum.

In the 2017-2018 school year, the district expanded the authentic professional development even further. The district opened up the working group, now known as the Science Champs Professional Learning Community (PLC), to include more teachers and had almost twenty science teachers in attendance at their monthly meetings. The group's ideas and suggestions led to even more specific professional development. For example, the Science Champs opened up their classrooms to each other to come observe teaching practices. The working group wrote up protocols for looking at different aspects of the classroom instruction during the visits. After the observations, the Science Champs reassembled, debriefed, and proposed some models of improvement that they could then take back to their respective schools and share with other science teachers. Ms. Taylor added, "KnowAtom™ actually facilitated all those meetings for us at no extra charge. This is how the partnership has grown" (personal communication, June 19, 2018).

Ms. Taylor explained that next year, the district has plans to expand the Science Champion PLC even further and make the PD even more meaningful. She described that the district plans to triple the footprint and cater to individual grade level bands. She clarified there will be kindergarten-to-second grade Science Champs, third-to-fifth grade Science Champs, and sixth-to-eighth grade Science Champs, who will all meet on different days, thereby making the feedback more specific and relative to those grade levels. She described that whereas before there were one or two Science Champions from each school, there will now be one from each grade level being represented at the new grade level PLCs.

According to Ms. Taylor, another PD initiative the district offered to its science teachers this year was to attend TEACH: The Next Generation STEM Conference, organized by KnowAtom™. TEACH stands for Teacher Exchange Allows Change to Happen. The conference, she clarified, was an opportunity for science teachers from around the United States to present to each other on best practices in STEM. Additionally, there were representatives from the Massachusetts Department of Elementary and Secondary Education as well as a keynote speaker. Ms. Taylor stated she is already excited about next year's TEACH conference, which will focus on making thinking visible with a growth mindset. Each of the teacher's experience with professional development with KnowAtom™ will now be discussed.

Using the interview protocol, participants were asked a few questions around professional development. They were asked how much professional development (PD) they had done with KnowAtom™, whether it was before or after implementation started, what strategies they took away from the PD, and how they felt about the curriculum after the PD sessions. The district took feedback from the teachers and adapted the PD it offered to better meet the needs of its teachers. This section will start with the perspective of the leadership, and then outline the teachers' experiences of professional development.

Gigi

Since each school in the study's district has autonomy, the individual science teachers have had varying professional development experiences. Gigi indicated she had her first KnowAtom™ PD before implementing the curriculum. She said it was very lecture-based and was an introduction to how the curriculum worked. Other similar types of professional development followed that she described as not being helpful. That all changed last year with the inception of the Science Champs. Gigi described, "We go into a school in the district that's implementing KnowAtom™, and observe in three classrooms a certain aspect like pacing or student-centered discussions, things like that, and that's better…because we get to see other teachers actually implementing [the curriculum]" (personal communication, June 14, 2018). Gigi recounted finding it very helpful to see another teacher implementing Socratic dialogue during a class observation and was amazed the teacher was allowing the students to fully lead the discussion. According to Gigi, the students presented themselves with the hardest question they could think of on the topic they were studying and, as a group, the class worked to use the knowledge they had gained from the nonfiction reader to answer each other's questions. The activity not only helped students deepen their understanding of the topic, while learning to be respectful and appreciate others' perspectives using accountable talk, but it also allowed the teacher to become aware of gaps in students' individual thinking. She further described that only half of the class, the inner circle, were discussing at a time, and the other half, the outer circle, were nonverbal and were either grading their partners in the inner circle or supporting them using information found in the readers or online. Gigi added, "The outer circle can also expand on the inner circle's discussion within a technology platform like KnowAtom's ™ SocraCircle®, which acts like a group chat" (KnowAtom™, 2018).

Lily

Lily reported having a different experience with KnowAtom™ PD. The summer before her school implemented the curriculum, the school held a summer training session with KnowAtom™ for the science teachers. A team from KnowAtom™ discussed the curriculum and led some hands-on activities so teachers could get a feel for what the units were like. Lily added that she has had at least six PD sessions specific to the KnowAtom™ curriculum thus far, but has also attended various KnowAtom™ webinars. She explained that even though the webinars are often during the school day, teachers can sign up for them and have access to the recorded webinar at a time that is more convenient to them.

Lily admitted the curriculum could be overwhelming at first, but noted, “The website that they have is fabulous, so that is really, really helpful. [KnowAtom™ gives] us the teacher’s guide and the student [guide]. You can see all the grade levels, [so] you can see where they’re coming from” (personal communication, June 14, 2018).

Lily stated one of the most helpful KnowAtom™ PDs she had was on Accountable Talk, what it looked like, and how to facilitate it. She further explained that the PD also gave ideas on how to set up the classroom to help create a better flow for conversation. This has helped her implement Socratic dialogue in her classroom.

Abbie

Abbie reported going to every professional development she could, participating in the ones her school offered during the school day as well as after school. Abbie said, “We had an absolutely stunning amount of professional development, and that’s when it started to unfold for me, ‘Oh, I got this!’…There’s such an ease to [the] step-by-step [progression]” (personal communication, June 14, 2018).

Abbie credited the PD she has received with helping her shift into a teacher leader role. In addition to PD support, Abbie said she also received a tremendous amount of support from her school’s newly hired science coach. It was an easy shift for Abbie to become what the district refers to as a “Science Champ.” She is now mentoring teachers of younger grades and, when she witnessed them feeling unprepared, she told them, “Guys, it’s so easy. You do this, then you do this. There’s such a beautiful progression.” (personal communication, June 14, 2018). Abbie attributed the logical progression and her role as a former ELA/literacy teacher, to knowing what scaffolds to insert at various phases for English language learners.

Sophie

Sophie mentioned she had access to the KnowAtom^{TM} curriculum and online resources over the summer before implementation, and had her first PD a few days before students returned. However, she said it was different once she had the students in the room. She advocated for authentic professional development and confirmed the PD had recently gone through a change. She said, “There's a group of teachers now going and visiting other classrooms, which I think has been by far the best PD, and I mean I don't even know if you'd call it PD, but the best experience we've had (personal communication, June 14, 2018).

From participating in the classroom observations, Sophie reported gaining insights into her own practice by watching both great lessons and lessons that were not going so well, and has incorporated strategies back into her own classroom. She relayed that seeing the good, the bad, and the in-between helped her understand things she was doing well and also gave her ideas about areas in her own teaching she wanted to adapt. Sophie said she has grown into the role of a teacher leader. She revealed she now opens her own classroom for observations, and has even led workshops and seminars for other science teachers.

Michelle

Michelle communicated that she has gone to countless KnowAtom^{TM} PDs including the TEACH Conference, and has now become one of the Science Champs. Her Dean of Curriculum was the first science champ at her school but, Michelle said after she received prompting from the Dean about her being more suited for the role, she stepped in to represent her school and has had a positive experience.

Michelle disclosed that the Science Champs met at a school and observed several teachers for about fifteen minutes. In these learning walks, she remarked, the Champs focused on certain indicators such as hands-on learning. According to Michelle, after an observation the Champs would debrief and then bounce into a new classroom and focus on a different aspect of teaching and learning. In these observations, Michelle was able to see a wide range of science classes. She reflected it was not about judging the teachers or their ability to teach, but rather the curriculum itself.

Luke

Luke's pointed out that he had a full day of PD before the school year started when his school first began the KnowAtom™ implementation. That full day was followed up with two other half-day PD that same year. In addition to attending the TEACH Conference, Luke described visiting other classrooms where KnowAtom™ was being implemented and had other teachers visit his classroom, although he is not one of the Science Champs.

KnowAtom™ representative

As a co-founder and CEO, Francis Vigeant has worked with many school districts not only in the United States, but in other countries as well. He stated that professional development is largely defined or constrained by district resources of time, money, and leadership. According to Francis, KnowAtom™ recommends for districts to start with PD before teachers get into the materials at all, so the company can discuss with teachers how to best utilize KnowAtom™ as a resource and as a thought partner to disseminate best practices. Francis said he has also learned that professional development tends to work best either by grade level or by grade span because there are very distinct needs and perspectives that emerge in those groupings.

Francis commented that professional development promotes ideal ways for teachers to do things, but teachers will only make changes if they see the value in it. Furthermore, he said he has often seen teachers adapting the change based on their students and their populations. The next section will discuss some of the ways the teacher participants have adapted their teaching practice with the KnowAtom™ curriculum.

Changes in Teaching Practices (RQ3)

KnowAtom™ co-founder, Francis Vigeant, outlined how Know Atom shifts instruction from teachers being the center of expertise to students being the center of expertise. "That expertise is something that grows as teachers assume the role of coach and facilitator for students" (F. Vigeant, personal communication, June 1, 2018). The participants in the study noted that releasing responsibility was one of the biggest and most difficult changes in their practices. The teachers expressed spending less time lecturing and more time guiding students to discover concepts on their own. Teachers acknowledged also giving students greater voice in the classroom. For example, discussions are now being led by the students through the Socratic seminars.

The teachers communicated shifting toward differentiating their instructions, allowing for more than one "right" answer and allowing students to move at their own pace during the labs. Furthermore, the teachers have shifted toward holding higher expectations for their students. Teachers now have a purposeful and progressive content alignment that asks students to do more reading and writing in science, use vocabulary in context, and model instead of recall information. The teachers' and administrator's experiences with these changes will now be discussed further.

Release of Responsibility

Ms. Taylor. As a district administrator, Ms. Taylor often observed teaching practices. She explained the biggest change she has seen in the teachers is with letting go and moving the control over to the students, allowing students to struggle just enough, and then coaching them toward understanding. She recounted that the teaching in her district used to be very teacher-directed, front-of-the-classroom teaching, and students were merely receivers of information. Ms. Taylor said the general method was to follow the gradual release of responsibility method, also known as the "I do, we do, you do" method (personal communication, June 19, 2018).

Additionally, Ms. Taylor said she had seen teachers giving students the platform to really think and talk to each other on a sophisticated level using academic vocabulary. She added that some teachers have even brought in technology in the form of the SocraCircle ® application to facilitate these discussions.

Gigi. Since the implementation of KnowAtom™, Gigi reported that she has increased instructional emphasis on nonfiction texts. In fact, Gigi pointed out that she has made that one of her foci for the first two years of implementation. She expounded that she has even reached out to ELA/literacy teachers, others on the science team, and administration for support with how to teach texts because she had not had the experience. She specified,

> Learning in college how to teach science did not include students reading text, and so I've had to learn and improve in that manner because the texts are really important, and so [is] teaching the kids to go back for information, use that text as a real tool, treat that text like a baby. (personal communication, June 14, 2018)

Lily. Lily disclosed she now spends less time lecturing. She admitted that before implementing KnowAtom™, she used to spend approximately sixty percent of her time lecturing to students and very little time doing hands-on activities. She noted that the boxed science kits she used previously had no reading component, and that required her to design the instructional component, often delivered in the form of a lecture. On the other hand, Lily explained, "KnowAtom™ has wonderful books, great vocabulary, really good investigations, excellent open-response questions, helping [students] prepare for their writing. It definitely has the science, technology, engineering, and math. It just covers everything" (personal communication, June 14, 2018).

Lily reported another shift she has made is asking students to reflect on their learning through discussion, which KnowAtom™ refers to as Socratic dialogue. She now holds students accountable for not only reading the text, but using the resources in the text and from their peers to delve even deeper than the text goes. Students use discussion time to make connections to the real world. She said this shift has helped her get away from doing all the talking in the classroom. She explained she now views her role as a facilitator and prompts students to use accountable talk with sentence starters. If students stall in the discussion, she gives prompts like, "I'm wondering" or "I'm also thinking" to keep the conversation moving along (personal communication, June 14, 2018). She also admitted she still has to help her fourth grade students learn to wait their turn because they do enjoy debating.

Abbie. Abbie divulged releasing responsibility to the students was by far the biggest shift in her teaching practice. While there is teaching that goes into setting up those processes, Abbie commented it has been rewarding for her to see students making decisions and taking ownership for their decisions. She said she was initially fearful about releasing responsibility. She wondered what would happen if the students did not do it right, but what she found was astonishment. She recalled that there were times she would be amazed because students would come up with something she never would have thought of. To be successful at releasing responsibility, she said she would often reflect on the standard she wanted them to learn, and would remind herself, "It doesn't matter if their procedure looks nothing like what I have thought about, they understand the standard" (personal communication, June 14, 2018).

Adding the Socratic seminar is also a new change for Abbie. She said it has been life changing for both her and her students. She was terrified of putting students in charge of discussing the concepts, but it has become an important part of her practice. She provides graphic organizers to help them organize their thoughts for the Socratic dialogue. Abbie's students look forward to their discussions and, in the process, she has learned more about their thinking processes.

Sophie. Getting the students to do more of the talking through Socratic dialogue has been a huge shift from what Sophie was previously doing in her classroom. Sophie stated she used to run a teacher-directed classroom, leading tons of Smart Board® lessons, in which she talked through the materials with visuals. She reported feeling that style was effective for the low-level recall of previous standards. She exclaimed, "I've never done anything like Socratic seminar before, so I think it's really neat to see the kids communicating and talking and becoming independent thinkers and listeners and responding to their peers. It's a really powerful tool" (personal communication, June 14, 2018). Sophie described using a particular set up with half of the students being in an inner circle and the other half of the students in an outer circle, giving each student a role and responsibility to come prepared with questions ahead of time. She reported the class now being more student-centered, involving more class discussions, more students talking amongst themselves, and more students working hands-on.

Sophie explained that after students have read nonfiction texts and participated in the Socratic seminar, they start the hands-on investigations. She reported that she previously gave students the information versus having them reading, discovering the material, or figuring things out with a lab. Sophie said her teaching practice has now shifted the way in which the investigations and activities are done, which she described as “controlled chaos” (personal communication, June 14, 2018). She explained that she now allows students to be at different places in their labs because students are not all the same and are not going to process information or reach conclusions at the same pace as their peers.

Sophie stated that transitioning from being teacher-directed to assuming the role of facilitator has allowed her to move around the room and check in with groups and ensure students are working efficiently. She conveyed observing that as her students see other groups checking in with her to move forward to the next phase of their investigation, it pushes them in not only their speed, but also their teamwork to get the task done so they, too, can move on to the next step.

Luke. Luke estimated he used to spend at least sixty percent of his time lecturing to the students. Before KnowAtom™, there was no reading in Luke’s class, so he reported feeling the need to impart the knowledge to the students in some way and lecturing seemed to work. He said his class lectures were not based on standards, but instead “were based on the ideas that were perceived to be needed for the kids to know…things that were being tested, but not necessarily aligned to a standard” (personal communication, June 19, 2018). Luke described spending less time lecturing now and more time with students reading, discussing, writing, and doing hands-on activities.

Michelle. Learning to be more of a coach or facilitator and less of a lecturer was something that has changed in Michelle's teaching practice. Having taught for only four years, she shared that she was figuring out her own teaching style. Michelle expressed feeling fortunate because she had a great curriculum to use these past few years. She said

> The thing that's interesting with KnowAtom™ is, as a teacher, I have developed with the curriculum…So I think my teaching style, not even in science, is inquiry-based and I rarely answer questions. I just turn them back to the kids and really give that idea of them discovering their own learning. And like I said, I find that I implement that in other subjects as well. (personal communication, June 19, 2018)

Before implementing the NGSS-based curriculum, Michelle reported that she spent more than half the class doing explicit teaching, such as showing a slide show and introducing new information. During our interview, she stated that she no longer feels the need to stand in the front of the class and introduce everything. She now enables the students to discover the material through their nonfiction readers, guiding them through their exploration of scientific concepts.

Differentiation

Ms. Taylor. Ms. Taylor recalled how science used to be in her district. She said that every student did the same experiment or, as was often the case, there was only enough materials for the teacher to do a demonstration at the front of the room and students would watch, comment, or record. She described observing a drastic change, as collaboration and teamwork are now promoted between students. She explained that students are encouraged to come up with their own ideas, their own hypotheses, and their own procedure for testing their hypotheses. Furthermore, she continued, students are pushed to experiment and try different approaches to solving a problem and, if they get stuck, they are told to consult with other teams and cooperate to find a solution.

Gigi. Gigi asserted one of the biggest shifts she made in her teaching practice was giving her students more choice in the classroom. Gigi noted that with her previous curriculum, what the students were expected to do was pre-defined, meaning everyone did the same investigation and all students' answers were similar, whereas the KnowAtom™ curriculum allows for a variety of outcomes. Gigi explained that students are expected to come up with their own questions to investigate, so it is possible for every group in the class to be working toward answering a different testable question within the constraints of the materials available to them.

Lily. Lily stated that she differentiates instruction by pre-teaching the vocabulary with visuals, which is a recommended strategy for English language learners (Allum, P., 2004; Chalmers, H., 2015). She admitted that this does slow down her pacing from what is recommended by KnowAtom™, but consciously provides this scaffold to make the text make more accessible to her language learners. She revealed that by helping all students access the vocabulary, the classroom discussions are full of strong academic language.

Abbie. Prior to the KnowAtom™ implementation, Abbie said all of her students were doing the same thing at the same time during labs. She recalled that she would model for students and then let them do it. Now, she acknowledged that her students might all be at different places in a lab. She explained that students have their instructions and their check-ins and work with their lab partner to plan and execute the lab. Abbie went so far as to say,

> There are times when, honestly, it's sort of surprising for kids. I'll have to announce, "Alright, boys and girls, there's going to be a little bit of teacher talk now, and that's kind of an unusual thing, because they know to look at all the science posters. Nobody asks me

> anymore, What do we do next? Oh, you just look on the science poster. What is the Scientific Method? So they know; they ask each other". (personal communication, June 14, 2018)

Sophie. The way Sophie facilitates her labs now has been another shift in her teaching practice. She reported that she also allows her students to be at different places in their labs, but makes sure they are all working toward their outcome. While it might look like what Sophie referred to as chaos, students are actively engaged in their learning and accountable for their choices.

Luke. Luke admitted that he used to have a strong focus on vocabulary acquisition. His tests centered around vocabulary recall. That has changed. He explained his tests are now differentiated for students, meaning there is not always one right answer. Students are given scenarios and are expected to use their knowledge to provide evidence for their claim, while using vocabulary in context. His expectation has changed to a higher-level application of the terms.

Michelle. Michelle stated that she still provides vocabulary support for her English language learners and students on Individual Education Plans (IEPs), but the students are now finding the information as opposed to being given the information. She went on to explain that as the students read, the class discusses what is being read. Michelle said she facilitated these discussions, but the students are the ones providing the information. To offer additional support, Michelle makes guided worksheets to help students prepare for the Socratic discussion. She remarked that she feels these supports have been key to her being successful with the program.

Adjusting Assessment of Student Capacity

Ms. Taylor. Ms. Taylor, the district administrator, reflected that she has seen teachers have their students do more writing in the science classroom. Ms. Taylor stated, "I can remember in one of the early PDs with KnowAtom™, a seventh-grade teacher raised her hand and said, 'You can't expect us to have students write in science, right? We don't do that in science'" (personal communication, June 19, 2018). There was no expectation that reading or writing was part of a science curriculum.

The most important change Ms. Taylor has implemented in her district is in the amount of science that is being taught. She reported science is now taught in every grade level, starting in kindergarten. Ms. Taylor made an honest confession that is similar to much research. She revealed that when she was a principal of a kindergarten-to-fourth grade school, science was not high on her agenda. She explained that students were tested in ELA/literacy and mathematics, and funding was tied to those outcomes. Ms. Taylor said she now recognizes that science is important and has many cross curricular opportunities. She conveyed that teachers report back to her that the reading and writing and critical thinking in science is helping in both ELA/literacy and mathematics.

Gigi. Seeing the students develop literacy skills has made Gigi have higher expectations in general for her students. She clarified that she no longer just provides the content for her students nor holds them accountable for low-level recall, but she now also expects them to use their critical thinking skills, model their understanding, and engage in a discussion about a topic.

Lily. When describing her former labs, Lily compared it to playing with sand and mud. She recalled that behavior was sometimes an issue. Now that students are held accountable for developing and executing their own lab activities using quality science materials, she reported noticing that they are less distracted and their behavior is better.

Abbie. Abbie reflected that she used to spend at least half of her time lecturing and, when she did do hands-on activities, there was not much analysis and evaluation of what students were doing. She admitted that her students liked science, but she was not teaching them to apply the knowledge they were gaining to a different set of circumstances. Abbie expressed that the KnowAtom™ curriculum has prompted her to hold her students accountable for critical thinking and problem solving, something that was missing in her previous teaching.

Luke. Luke said the KnowAtom™ curriculum used the scientific method and engineering design process throughout, which is something he did not do before. He commented that he now uses these to guide his students' writing in their lab notebooks. Luke commented,

> [Students] do a lot more writing in class. We do a lot more hands-on activities. I do less lecturing, …they now discover more through the inquiry-based [activities] that we do with this program. So I'm more of a guide than I was before. I'm less of a lecturer and more of a guide. (personal communication, June 19, 2018)

Holding students to a higher standard is something else that Luke revealed has changed in his practice. His tests are no longer merely a place for vocabulary recall, but rather a place to show mastery of material while using vocabulary to explain the concepts. Luke disclosed that he has still struggled with releasing responsibility to the students, a recommendation of the NGSS. He explained the students come to him from fourth grade with no science background, and as such, do not yet know how to write a lab or formulate a hypothesis. However, he pointed out that his school just adopted KnowAtom™ in fourth grade, so he knows it will be different soon. But he admitted that until he knows the students are ready, he will maintain much of the control in his classroom.

Michelle. Before KnowAtom™, Michelle disclosed that she was piecing together what she could, but not aligning them to Massachusetts science standards. She admitted she can now see that was an ineffective teaching strategy. She reflected, "I was just batting in the dark. I didn't see a scope. I just went topic by topic" (personal communication, June 19, 2018).

Michelle asserted that her labs were also very different before. She expounded that she would give students an easy handout for them to fill in missing spots, which required low-level cognition, but aligned to her expectations for her students. Even when she first received the KnowAtom™ curriculum, she thought, "My kids can't do this. We always had such lower expectations for them" (personal communication, June 19, 2018). Michelle gave an example of the change. She said that instead of asking students to recall the difference between weather and climate, her students now analyze data from a certain area to describe the weather and climate of a region and specify what factors contribute to changes in the weather and climate. Students are expected to not only grasp the content, but additionally to be able to apply it. She pointed out that this type of activity better prepares the students for the types of questions being asked on the new standardized tests aligned to the NGSS.

Michelle credited the KnowAtom™ curriculum with helping her become the teacher she is today. She also credits KnowAtom™ with changing her belief about what her students can accomplish. She reflected that her previous belief was, 'My kids can't do this, because we always had such lower expectations of them" (personal communication, June 19, 2018). She reported that the curriculum has helped her change her approach to science instruction as she saw the importance of hands-on learning that challenges students to use higher order thinking skills.

She now asks students, “Come up with the hardest question you can, but that you can figure out” (personal communication, June 19, 2018). She then guides them to work together to find the answers to those questions. Michelle has witnessed time and again her students rise to the challenge, and subsequently made her professional goals this year to hold high expectations of all her students.

Teachers implementing the KnowAtom™ curriculum have made some significant shifts in their practices. While they indicated releasing responsibility was the toughest change to make, they also reported they have found fulfillment in the new classroom culture that has emerged from the change. Teachers also guided the students toward accepting more responsibility for their learning, giving them freedom to make choices about the pace and direction of science investigations and laboratories. Teachers expressed having higher expectations of their students, yet providing the supports students needed to reach those expectations as depicted below.

Table 3

Changes in Teaching Practices

Changes in Practice	**Category**
Assume role of facilitator Spend less time lecturing Facilitate Socratic dialogue Students discover concepts	Release of responsibility
Allow for more than one “right” answer Allow students to move at own pace in labs Pre-teach science vocabulary	Differentiation
Purposeful and progressive content alignment Students do more writing in science Students model instead of recall information Students use vocabulary in context	Adjusted assessment of student capacity

Changes in Student Outcomes (RQ4)

This section describes the changes in student outcomes reported by teacher participants. These changes in student outcomes include improvements in class collaboration, students' test scores, classroom behavior, communication skills, and student engagement and participation. The results are subsequently described by finding.

Increased Collaboration

The following section details reported examples of increased collaboration. One-third of the teachers expressed finding enjoyment in seeing the students collaborate during labs and investigations as a result of the KnowAtom™ curriculum. Abbie clarified that the students are asked to work together as a team to complete one step of the investigation before they can move to the next step. Furthermore, students cannot proceed with the next steps until their whole team has completed the first step of the investigation. Abbie admitted that it took a lot of work at the beginning of the year to coach students in how to help a teammate who was struggling. She shared her belief that it was motivating for her students to help one another because they know they only succeed if their whole team works together. Abbie stated that her students are driven to get to the scientific investigation or the engineering design portion of the KnowAtom™ unit, so there is incentive for them to support the whole team. She confessed that her students do occasionally need some extra guidance from their teacher, but it does not happen often. Abbie said

> We spend a lot of time at the beginning of the year on how to help everybody be successful [and] how to be a team. And all that is built in to the process of working as a team, and then getting checked off with each part. (personal communication, June 14, 2018)

Abbie stated that the freedom she gives students in choosing their teams has also encouraged a supportive culture to be developed in her classroom. While she gives some freedom and choice, she commented that she also gives teams a timeline for starting and finishing the investigation. Abbie indicated this was an effective strategy because students are highly motivated to get to the investigation. She specified that there are also status checks along the way. Therefore, she revealed that if she sees a team in trouble, she encourages them to consult with another team to get tips for how to complete their current task. Abbie also said that giving students more ownership has made her more available to move around and offer additional supports to teams that are struggling. She continued that if teams did not work well together and, subsequently, did not get to the investigation, they knew they can choose a different team next time. Abbie commented, “I think that has been one of the most exciting things- seeing the growth and maturity of kids to be able to say, ‘We shouldn’t work together. We did not do well.’” (personal communication, June 14, 2018)

One incident that stood out to Abbie, which she relayed during our discussion, occurred after her students had completed an engineering design problem. She said the students were engaged in a Socratic discussion and one student posed, “Would you recommend for the library to purchase your prototype?” The other student responded, “I don’t. I wouldn’t buy our prototype” (personal communication, June 14, 2018).

Sophie shared that her students enjoy collaboration with the Socratic seminars. She explained that some students are sitting around the inside table and some are sitting in an outside circle, and the students at the inside table are the ones who are talking. She noted that everyone is respectful of the process because Sophie said she establishes those norms early on in the year so that students learn how to agree and disagree and talk respectfully with their peers.

Improved Test Scores

There were reports of higher test scores by teachers participating in this study and more generally by several of the district's schools implementing KnowAtom™. Lily reported seeing an improvement in her fourth-grade students' nonfiction reading scores. In Massachusetts, students are not tested in science until fifth grade. However, younger grades do still have to take ELA/literacy and mathematics standardized tests. One part of the English language arts MCAS is reading. Lily reported seeing a connection between the students' ELA/literacy scores and the KnowAtom™ curriculum, making her feel her students are benefitting from reading the nonfiction text with KnowAtom™. In fact, she relayed that some of her students scored highest on the nonfiction section of the reading tests they recently took.

Michelle noted her students had a big increase in their mathematics performance between last year and this year. She stated that her school just did the MAP (Measure of Academic Performance) testing for mathematics and the students showed huge growth. In fact, she said her school displayed the highest in the district. She attributed this to the background knowledge students are getting in science that they are able to apply to other subjects, as well as the crosscutting concepts with the NGSS. Not only do the crosscutting concepts link different domains of science, but they also relate to mathematics. They include patterns, cause and effect, and scale, proportion, and quantity as noted in the *Framework* (National Research Council, 2012).

Sophie reported her students having big gains in their science standardized test scores. She added that even students, who started out lower than their peers, ended up testing at a similar level as their peers. Moreover, a majority of her students tested proficient in science, something that had been previously unheard of for her district.

A review of recent assessment data revealed that after two years of using the KnowAtom™ curriculum, the district had ten percent fewer fifth grade students and twelve percent fewer eighth grade students on warning on the state standardized test across the district, but the difference was even greater for English language learners (MA DESE, 2018). Fifth grade ELLs had a fourteen percent reduction and former ELLs had a thirty-two percent reduction in students who were on warning. Eighth grade former ELLs had a thirty-three percent reduction in students on warning (MA DESE, 2018). Ms. Taylor stated "Not only has there been drastic reduction in our learners scoring in the lowest regions of warning, as a result of having science and having KnowAtom™. We're also seeing increases in proficiency" (personal communication, June 19, 2018).

Ms. Taylor relayed that last year, one of the teachers in the district, who really embraced the idea of Socratic seminar not only outperformed the district in fifth grade, she also outperformed the state significantly. Ms. Taylor added, "Having 70% plus students at proficiency level in science is unheard of for our district" (personal communication, June 19, 2018). She noted that other teachers had become intrigued by the success and were hoping to institute similar changes to their practice.

Ms. Taylor reported the schools also recently gave the MAP test in science and the results were looking very positive. She said she was encouraged by the scores and was hopeful the science MAP results will be a predictor of future state mandated testing in science.

Better Classroom Behavior

Three of the teachers mentioned noticing students had more control over their behavior during science. Lily reported finding that her students' behavior is better when there is hands-on learning. She conveyed that once students get the materials in their hands, they absolutely love it. She said there is less distraction from behaviors because the students are engaged.

Abbie's school has many students coming from high poverty and with a tremendous background of trauma. Abbie clarified that many have recently immigrated with little time to acclimate, so teachers sometimes have to call and have a child forcibly removed from the room. Abbie said she has never had to have a child removed from her instructional space, and attributed the calmer behavior to the students being engaged in active, hands-on learning. The students are always moving, which she stated was very helpful to all students.

Abbie also attributed better team behaviors to giving the students more choice in their labs and investigations. She remarked that when her students do not work well together, they accept the consequences. She recalled, "Students are learning the reason they did not get to the investigation because they were socializing too much" (personal communication, June 14, 2018). Abbie admitted it was initially very hard for her to let the students fail to get to the investigations because they eagerly look forward to them. She reflected, "Those are the things that are so much bigger than science. They are learning these hard lessons about how to interact responsibly with others to achieve a shared goal" (personal communication, June 14, 2018).

Sophie shared her belief that science is a great place for students with behavioral problems or even attention problems in general because they love science and they love to build things and work with their classmates. She said her classroom is definitely not always a quiet place, nor is it perfect, but it is a place where a lot of students find success.

Improved Academic Vocabulary and Discourse

Four of the teacher participants attributed stronger academic vocabulary and discourse to the KnowAtom™ implementation. Gigi noted her students have an increased used of science vocabulary during topical discussions. She relayed that her students are also using the vocabulary to connect back to previous concepts learned earlier in the year. She commented, “Using the vocabulary has definitely improved, so has their ability to talk about a topic” (personal communication, June 14, 2018).

Lily commented that her students are also using vocabulary, even as fourth graders. She continued that when a previously-learned word would come up in class, a student would exclaim, “Oh, we know that word. I know that word from third grade” (personal communication, June 14, 2018).

In Abbie’s fifth grade class, she relayed that she had students who are reading well below grade level or who cannot read at all. However, this has not deterred those students from being able to discuss scientifically. Abbie expressed finding enjoyment in the quality of the student readers and feels they are very ELL friendly. The described that the vocabulary is bolded; there are pictures; and there are graphs. Abbie offered

> The kids are all coming in at such a level playing field because nobody walks in knowing what photosynthesis is, so it's so cool to hear kids who don't know that much English, yet they know about photosynthesis and can talk about it. So I think the hands-on aspect of KnowAtom™, the ... graphics, all the things that we put in place to support them just helps them feel successful. (personal communication, June 14, 2018)

Abbie communicated noticing improved communication skills for her English language learners. She relayed a story about a student, who entered the U.S. two years ago. She described that for a test question, students were asked to decide whether light or sound was better for transmitting information within a realm of constraints. She said her student was able to use tier three vocabulary words such as prototype, priority, contradicts, effective, and transmitting. Abbie attributed this to the students' constant exposure to and use of academic language in class.

Sophie reported her school having a schoolwide focus on accountable talk, which refers to talk that is meaningful, respectful, and mutually beneficial to both speaker and listener. She said that she tied the school goal to her teacher goal, too. She conveyed believing Socratic seminar fits in nicely because students had to use accountable talk to discuss concepts with each other. She said students would use phrases such as, "I agree or disagree with ___ because ___. Could you explain a bit more please? What is your evidence? I am confused about ___. I was thinking about what ___ said, and I was wondering what if ___" (Education Closet, 2015). Sophie now steps back and lets students run the show. Sophie commented,

> [Students will] say, here's the question, here's my answer, who agrees with me, who disagrees with me? And they get to the point where they're asking their peers, now why did you choose this? Why do you disagree? Why do you say that I'm wrong? So I think that's definitely helped with that conversational piece more so than anything else, that it's okay to say I don't agree with you. Let's have a conversation about it, versus oh, you must be right, I must be wrong. So I'm just going to change my answer. And it's a process that's taken a long time to get to this point. (personal communication, June 14, 2018)

Increased Engagement and Participation

All of the teachers and the district administrator reported an increase in engagement and participation. Gigi reported observing her students demonstrating greater curiosity in class. "They know about a topic and can talk about it. They can ask questions and think deeper about it" (personal communication, June 14, 2018).

Lily described having the same experience. She said her students are always excited when a new unit starts. She commented, "It's…the enthusiasm. All of the investigations are really exciting" (personal communication, June 14, 2018). Lily reported finding that the students are making the connections to other things they have learned.

Abbie said she includes her students in the process from the beginning. She explained that students read the nonfiction texts and discuss the concepts found in the text. They make connections to their experiences and the experiences of others about the topic. Students are peer-graded while doing the Socratic discussions to hold them accountable. Students also choose their own teams and work through the entire lab, investigation, or engineering design challenge together. She concluded that everyone has a role or responsibility for each of the activities found within each unit.

Sophie reported finding increased participation, especially during Socratic seminars. She reported that each of the students has a role during the discussions, and that being accountable for these roles has helped reduce much of the behavioral problems she described having witnessed in the past. Additionally, she expressed observing increased engagement during the labs and activities. The KnowAtom™ curriculum provides not only the materials, but also the performance expectations that students will perform. She expressed seeing that even the students with attention deficits have done much better.

Luke reported noticing his students' engagement to be greatly increased. He stated that every student is involved in some way during the writing of the lab, as well as during investigations and activities. Luke said his students know when they come to science, it is to work. He is no longer just rolling out materials and allowing students to play with them. Science class now involves answering questions and engineering solutions to problems. It makes it more legitimate and students want to come. Luke commented,

> It's that inquiry piece that gets them involved but this program gives legitimacy to the use of those materials because you've already written a lab that tells you where you're going. So those materials mean something to the kids when they get them in front of them. It isn't just play time it's, 'Okay, this is the task I have at hand', but again, they're engaged and they're ready to go and solve that problem or answer that question. (personal communication, June 19, 2018)

Michelle has reported seeing her students be more enthusiastic about learning science. She said she made guided notes to help the students while they are reading the text. She relayed that her students enjoy the success they feel as they read and have turned it into a scavenger hunt game; they are finding ways to keep the learning fun. She communicated that the students' entire work ethic has changed and they see the text as a tool to find the answer they are seeking.

Ms. Taylor offered anecdotal data to support increases in engagement. "Students are in the hallways and the stairwells because they're testing different prototypes. These are things that just did not happen on this level before" (personal communication, June 19, 2018). Ms. Taylor reported finding enjoyment in seeing the KnowAtom™ provided materials in the hands of the students, allowing students to explore and get curious about further applications of what they are discovering. Moreover, she relayed that the students, who are second language learners, and who may not be able to read at all in English, are working with their peers, contributing and understanding and able to offer so much meaningful information. In essence, the KnowAtom™ curriculum provides access points for all learners.

Changes in Teachers' Beliefs and Attitudes (RQ5)

After implementing KnowAtom™, the teachers in this study have not only adapted their own teaching practices, but have also transformed their expectations of what students are capable of doing in science as a result of the curriculum. This section provides an overview of how the teachers' beliefs have changed as a result of seeing their students engage in performance tasks with KnowAtom™. Four themes emerged from the data: science connects well with other core subjects; student collaboration can greatly impact learning outcomes; the responsibility of learning should be shared with students; and student demographics should not dictate teacher expectations.

Science Has a Strong Connection With Other Core Subjects

Three of the teacher participants reported the curriculum providing connections to other core subjects, namely mathematics and ELA/literacy. Gigi reported feeling initially frustrated with the KnowAtom™ curriculum because it did not follow the model she was used to teaching; however, she has grown to appreciate how it connects in more authentic ways to the mathematics and ELA/literacy standards and skills. She expressed her new belief that it is fine for students to struggle through a task, and even good for them. Gigi attributed her changes in attitudes and beliefs to the NGSS-designed curriculum. She shared,

> [The curriculum] is focused on those next generation skills, those science and engineering skills. And if they're learning a skill, they're going to struggle until they learn it, as opposed to memorizing information. There's not really a productive struggle there. There might be a struggle to memorize or recall, but it's not a productive struggle. It's just a struggle. (personal communication, June 14, 2018)

Gigi stated that the old science frameworks were focused mainly on content. The new frameworks include content, but have a stronger focus on science and engineering practices. She said students learn the content through engaging in the science and engineering practices, noting that it is practical learning by doing instead of merely recalling material.

Sophie expressed being a big advocate for having authentic science instruction starting as young as possible. She relayed that her school does it from kindergarten to eighth grade. She said the students are coming with more background knowledge and it is helping with overall improvements across the K-12 spectrum.

Luke stated that having students integrate more writing in the science classroom is the component that has changed the most for him. He now sees the value in having writing in science. He conveyed that when his students write out their hypotheses and lab procedures and formulate and write their conclusions, they are working on the organizational skills that carry over from and back to their language arts classes.

Student Collaboration Can Greatly Impact Learning Outcomes

The KnowAtom™ program encourages collaboration in the form of Socratic dialogue and partner and group work, and the teachers have taken notice. Abbie reported having a new way of thinking about students' ability to grasp difficult concepts and defend their thinking. She shared that her classroom is now full of strong discourse, and there is not necessarily just one correct answer.

Sophie expressed her belief that the Socratic discussions are a great place for students to either showcase what they know or say what they do not know. She commented that it allows students to be really honest with their peers and allow for supportive and corrective feedback. Students learn to discuss with facts instead of opinions. Sophie specified that learning to respectfully agree or disagree with others is a 21st century skill students have to learn for the rest of their lives, although it may be challenging for a ten- or eleven-year-old.

Sophie reported seeing increased collaboration with the science labs and activities, too. She said her students learn how to come together and work together to complete the science investigation or engineering design process, even if they are not the best of friends. Sophie expressed her belief that it is the development of these 21st Century Skills that are producing those aforementioned positive student outcomes

Responsibility of Learning Should be Shared with Students

Releasing responsibility to the students was the biggest shift teacher participants made in their practices. With the positive student outcomes, teachers are reporting a change in their belief about the power dynamic in the classroom. Abbie relayed that she has embraced releasing responsibility and becoming a facilitator in her classroom. She reported feeling this has taken a lot of pressure off her to teach her students everything. She said she now believes it is fine for her students to be doing different things at different times, because they eventually all end up in the same place, but with different outcomes. Ultimately, students are meeting the standards, but it may look different for different groups of students, which Abbie described feeling is differentiating for all learners.

Sophie reported now being a full believer in releasing responsibility to her students. She expressed knowing that in order for the ideas of the curriculum to work effectively, she would have to be faithful in her adherence to it. After seeing her students' science scores be better than she ever could have imagined, Sophie said she has completely bought into the process. She commented that teaching science this way takes longer but, when even her lower students ended up in a similar spot to their peers, she knew it was a better way for her to teach.

After twenty-five years of teaching, Luke said he patted himself on the back for making any change in his teaching practice. Luke expressed that he is starting to believe it is okay for him to release some responsibility to his students. He conveyed that he has given his students much more control over classroom decisions and how to approach problems than he ever would have before. He admitted he still has a long way to go, but he is making great progress toward that personal goal.

Michelle reported being initially overwhelmed with the KnowAtom™ curriculum because it asked teachers to change their teaching style, turning over ownership of the classroom to their students. She stated, “But now, I love KnowAtom™. I couldn’t imagine teaching science without it now because of how accustomed I’ve gotten to these really quality resources available [and] the steps that are there for you” (personal communication, June 19, 2018). She said she has released much responsibility for learning to the students and enjoys being a coach.

Student Demographics Should not Dictate Teacher Expectations

The teachers in this study reported seeing their students rise to the expectations set for them and have shifted their beliefs about what their students are able to accomplish. Lily stated it has been eye-opening to see that her students being able to handle a curriculum as rigorous as KnowAtom™. Lily clarified that many of her students are English language learners and others are grades behind in reading. She reported seeing them find success with the vocabulary and really enjoy the readers. Lily expressed excitement to see the results of this year’s science MCAS for the students she had last year.

Michelle admitted she had lower expectations of her students before implementing KnowAtom™, but now holds them to much higher standards. She said she has seen her students rise to the new challenges, too. Michelle acknowledged that she is not always sure what level to expect of her students, but KnowAtom™ has pictures and models of exemplar student work and the illustrations help keep Michelle on track in her level of expectations.

Even though Sophie uses KnowAtom™ as directed, she was quick to point out that she does scaffold with visuals to help some of her students, who are visual learners or English language learners. She said she also has supportive discussions while reading the nonfiction text to adapt for students, who are below grade level in reading, while still holding them to a high expectation. She reported finding that making those adjustments to her teaching practice, while staying true to the process has made a difference in the outcomes of her students.

District Administrator, Ms. Taylor, commented that several of the district's science teachers were brave enough and honest enough to say they did not think the students could do the curriculum. Ms. Taylor reported teachers saying, "The grade level reading is really high and the rigor is tough. We can't expect them to write a lab report on their own or create their lab notebook" (personal communication, June 19, 2018). She indicated that teachers are now saying the students are surprising them and the teachers are so amazed at how much the students can actually do and learn when the level of expectation is raised.

As a KnowAtom™ trainer, Francis reported observing teachers, who feel a strong need to adapt the level of reading for English language learner students or those behind grade level in reading. He said the teachers were pushing for leveled readers. However, over the course of the last three years, Francis stated that those same teachers have gotten creative with helping struggling readers access grade-level reading and the results have been phenomenal. Francis shared that one of the biggest increases in the district was for ELLs. He said those same teachers now believe in holding *all* students to a high level for reading, but giving them the scaffolds necessary to reach the level. A summary of these findings can be viewed in the table below.

Table 4

Changes in Beliefs and Attitudes

Changes in Beliefs and Attitudes
Science has a strong connection with other subjects
Student collaboration can greatly impact learning outcomes
Responsibility for learning should be shared with students
Student demographics should not dictate teacher expectations

Summary

The aim of this chapter was to provide the findings and themes that emerged from the data collection done in this study. The National Research Council's (2015) *Guide to Implementing the Next Generation Science Standards* have called for changes in science education. Science education now involves less rote memorization of facts and terminology, less ideas disconnected from questions about phenomena, less of teachers providing information to the whole class, less of teachers posing question with only one right answer, less pre-planned outcome for "cookbook" laboratories or hands-on activities, and less worksheets (National Research Council, 2015).

According to the National Research Council (2015), today's science education involves students using facts and terminology to support evidence-based arguments and reasoning; conducting investigations, solving problems, and engaging in discussions with teachers' guidance; discussing open-ended questions that focus on the strength of the evidence used to generate claims; carrying out multiple investigations driven by students' questions with a range of possible outcomes that collectively lead to a deep understanding of established core scientific ideas; and students writing of journals, reports, posters, and media presentations that explain and argue. The KnowAtom™ curriculum was designed specifically for the NGSS. Therefore, teachers are having to change the ways they deliver science instruction. They are releasing responsibility to the students, differentiating instructional approaches, and holding higher standards for their students. Teachers have taken on the role of facilitator as students read and discuss the nonfiction texts. Teachers have also allowed students to be at different places in the lab activities and allow for more than one outcome. They are holding students to a higher level in reading, writing, and showing mastery of knowledge and skills.

Moreover, the teachers have needed support to make these changes. The school district had to change the way they were providing professional development from lecture-directed to hands-on activities and authentic learning walks. These changes in practice, as well as changes in the way PD was delivered, have also had positive outcomes for students. Teachers saw an increase in collaboration, improvement in test scores, increase in academic vocabulary and discourse, and an increase in participation. They also saw students more engaged, which resulted in better behavior in the science classroom.

The teachers in this study have changed some of their beliefs about how science instruction should be done and about the abilities of their students. The first notable change in the teachers' beliefs was that science has a strong connection with other subjects, especially when purposeful alignment is made with the Common Core's math and ELA/literacy standards. The second shift in belief was that student collaboration should be encouraged because it can greatly impact learning. The third shift in belief was that the responsibility for learning should be shared with students. The increase in participation and engagement had a strong correlation to teachers giving students more choice about their learning. The fourth shift in belief the teachers made was understanding that student demographics should not dictate teacher expectations of students. Instead, teachers should hold high expectations of all students. It has been the application of the KnowAtom™ curriculum, as well as the district's response to implementing the curriculum and building sustainable teacher-driven PD that has made the implementation successful.

Chapter 5: Discussion

The purpose of this qualitative instrumental case study was to identify the types of changes that grade four and five science teachers have had to make in their teaching practices in response to the Next Generation Science Standards. Based on the *Framework for K-12 Science Education*, the Next Generation Science Standards view core ideas, science and engineering practices, and crosscutting concepts as being distinct, yet equally important components of learning science. This chapter includes a discussion of the findings in regard to the literature on science education and the NGSS. Also included is a discussion on this study's connection to educational practice change models. It concludes with a discussion of the findings, implications for theory, research, and practice, as well as suggestions for areas for future research.

This chapter contains discussion of and future research possibilities on the overarching research question of, "How have fourth and fifth grade science teachers changed their practices to implement KnowAtom^{TM}, a learner-centered, NGSS-aligned curriculum in their classrooms?" To answer this overarching question, the following research sub-questions, aligned to the conceptual framework, were used:

(RQ1): What were the participants' initial feelings about implementing the KnowAtom^{TM} curriculum?

(RQ2): What professional development opportunities were provided to the participants?

(RQ3): How did the participants shift their teaching practices to meet the demands of the NGSS?

(RQ4): What changes did the participants notice in learning outcomes for their students?

(RQ5): How did the teachers' attitudes or beliefs change after implementing the KnowAtom^{TM} curriculum?

The KnowAtom™ curriculum is built on an innovative approach to teaching science based on the NGSS, where teachers become facilitators of learning rather than givers of information. Because of individual school autonomy, the teachers received different types of professional development opportunities. The study highlights how teaching practice was transformed through curriculum implementation when teachers began to release responsibility to students, differentiate instruction for English language learners and students with disabilities, and maintain high expectations of achievement for all students. As a result of the KnowAtom™ curriculum implementation, district and building level professional development, and teacher leadership, changes to NGSS aligned teaching practices led to improved test scores and classroom behavior, increased usage of academic vocabulary and academically appropriate discourse, as well as increased student collaboration, engagement, and participation.

Interpretation of the Findings

The findings of this investigation aligned with current research in areas related to best science teaching practices. The NGSS expects students to construct knowledge while they are engaged in authentic science and engineering activities. This entails having a curriculum in place that is aligned to the new standards, enabling students to apply scientific practices, procedures, and inquiry-based collaboration in the context of a scientific concept.

The NGSS-aligned curriculum, as well as district level expectations for fidelity of implementation, was the catalyst for transforming teaching practices in this study of grade four and five science teachers. The implementation of the NGSS-designed KnowAtom™ curriculum required the study participants to rethink their attitudes and beliefs about teaching and learning science, and in turn, required that they implement a learner-centered, constructivist approach to delivering content. Constructivism is an interactive process where teachers and learners must work together to create new ideas in their mutual attempt to connect previous understandings to new knowledge (Anderson, 1996).

In order to meet the requirements of the NGSS and prepare its students for STEM careers, U.S. teachers have had to change their teaching practices (National Research Council, 2015). Facts and terminology are now being learned as needed while developing explanations and designing solutions supported by evidence-based arguments and reasoning. In the KnowAtom™ curriculum, students were using systems thinking and modeling to explain phenomena and to give a context for the ideas learned. Teachers reported that students were conducting investigations, solving real scientific problems, and engaging in academic discussions with their guidance.

Furthermore, the participating teachers' students regularly engaged in open-ended questions that focused on the strengths of the evidence used to generate claims, reading multiple sources, including science-related magazines, journal articles, and web-based resources, to develop summaries of information. The study discovered that teachers shared instances of multiple investigations driven by students' questions with a range of possible outcomes, collectively leading to a deeper understanding of the established core scientific ideas. In the participating teachers' classrooms, students wrote journals and reports, made posters, and created media presentations, explaining concepts and arguing positions. They were applying and practicing NGSS recommended 21st century skills. To enable success for all students, participating teachers provided supports so that students could engage in sophisticated science and engineering practices.

These were the kinds of activities found in classrooms implementing the KnowAtom™ curriculum. Within participating teachers' classrooms, this study documented notable paradigm shifts where teachers had previously operated by giving information to students and expecting memorization and recall, to expecting students to discover and explore scientific information and, subsequently, model their understanding of it. Engagement with the curriculum, coupled with district support and teacher leader capacity building was shown to develop classroom cultures that supported the new active vision of science education.

It has been documented that working with standards can be challenging (Monson & Monson, 1997), and that teachers need support to make the significant changes to their instructional practices (Ball & Cohen, 1999). Pruitt (2015) posited there must be a strong focus on developing educators in how to make the NGSS tangible in science classrooms. This requires extensive professional development that allows teachers time to collaborate and reflect on their practices (Penuel, Harris, & DeBarger, 2015).

Unfortunately, the current professional training of most educators falls short of preparing them to respond to the challenges that arise during such a dramatic curriculum change (Badiou, 2001). Liker and Meier (2007) found that teaching practice transformation comes from repeated practice with additional coaching, so unless professional development is embedded in the teachers' practice, it leads to superficial learning, but not real change.

The lecture-based, non-differentiated training on the KnowAtom™ curriculum initially provided by the school district was ineffective in preparing its teachers to implement the curriculum. As a result of this initial failure, the district responded by partnering with KnowAtom™ to create a new model of professional development that developed teacher leaders, who then went back to their schools and gave specific training and mentoring to other science teachers. This created a sustainable, trusted network of in-house professional development specialists. This supports the claim that curriculum change will never be realized without effective leadership through the change process (Burke, 2014; Swihart, 1971).

If a new program is to be implemented well, it has to become a natural part of a teacher's practice (Guskey, 2002). Teachers participating in this study reported finding enjoyment in giving students more ownership over their learning because it resulted in teachers having more time to differentiate instruction for other learners. As was apparent with this study's participants, there are challenges that may arise throughout the implementation process. Within this study sample, teachers had to adapt quickly and in the moment through the change (Penuel, Harris, & DeBarger, 2015). Earlier studies found unexpected challenges can create ambivalence or resistance toward the change process (Piderit, 2000; Tong, 2010), and this may be interpreted as a stage in the process of change as was evident within the implementation of KnowAtom™. The district administrator in this study reported viewing both positive and negative emotions as meaningful indicators (Klarner, By, & Diefenbach, 2011) and therefore responded by adapting the professional training provided to the teachers (Wong, 2001).

Skill sets vital to ELA/literacy and mathematics can be successfully integrated into the science curriculum, yielding positive student outcomes across content areas (Bybee, 2014). Teachers in this study reported using their ELA/literacy background or collaborating with ELA/literacy teachers to employ reading strategies for struggling students in order to access the KnowAtom™ texts. Additionally, the teachers reported seeing connections between science and math including recognizing patterns, cause and effect, and scale, proportion, and quantity (National Research Council, 2012). Participants attributed increased test scores (Andersson & Reimers, 2010; Pintrich, 2003; Soto Kile, 2006), better behavior (Bradshaw, Mitchell, & Leaf, 2010), increased engagement and participation (Polikoff, Le, Danielson, Sinatra, & Marsh, 2017), and increased collaboration (Star et al., 2015) on the cross-curricular nature of the KnowAtom™ program, and on the application of reading, writing, discussion, and math skills within each unit of study. As teachers saw positive evidence in the form of learning outcomes for their students, they exhibited belief in the value of the program and were motivated to align their teaching practices closer to those of the NGSS (Guskey, 2002).

Implications for Theory and Research

Chapter 2 referred to three change models: Lewin's (1947) "Unfreeze-→Change→ Refreeze model", Guskey's (1985) "Model of Teacher Change", and Fullan's (2007) "Educational Change Theory". Whenever an educational change happens, there is normally an initiator (Fullan, 2007), which causes the unfreezing (Lewin, 1947) or disruption to the norms. The implementation of the NGSS-aligned KnowAtom™ curriculum, coupled with district support, school-based and teacher-driven professional development, and the creation of a network of teacher leaders were keys toward changing teacher practice and improving student outcomes. Once teachers saw the positive student outcomes, the changes were institutionalized (Fullan, 2007), and the new practices became the new norm, or as Lewin (1947) would term it, the "refreeze" step.

While there is overlap in the change models, this study used the lens of Guskey's (1985) model of teacher change. According to the model, through professional training and positive student outcomes, teachers change more than just their practices. They also change their beliefs about their students. Analysis of this study's findings strongly support the notion that, given systematic support and evidence of positive student achievement both within the classroom and on standardized tests, teaching beliefs and expectations of student achievement can be positively impacted.

Professional Development

The teachers in the district initially required training on the Next Generation Science Standards and the KnowAtom™ curriculum in order to understand the alignment and structure of the curriculum. Francis Vigeant, co-founder of KnowAtom™, noted that implementing KnowAtom™ required teachers to shift the instructional culture. He stated his company took training teachers in the curriculum seriously because, if it just provided curriculum and materials with no professional development, the curriculum would be subject to the lens of whoever was using it (F. Vigeant, personal communication, June 1, 2018). This study also found that it was the curriculum, coupled with authentic professional development provided, that drove the transformation of teaching practice.

Guskey (1985) outlined that change is a slow, difficult, and gradual process for teachers. He found while teachers want to improve student learning, they are hesitant to implement innovations that require radical alterations in their teaching practice. To realize such a change, Guskey posited the professional development provided to teachers needed to illustrate how the new practices could be implemented without much disruption. This study found that, on the contrary, the NGSS required a significant disruption to teaching practices; however, with effective support in the form of applicable PD, the establishment of teacher-led professional learning communities, evidence of positive student outcomes, and a long-term commitment to the success of the program, both teaching and learning were transformed.

Staff development has the purpose of bringing about change (Guskey, 1985). However, research suggests the professional training of most educators falls short of preparing them with the knowledge, dispositions, and capacities to respond to challenges (Kesson & Henderson, 2010). When the PD KnowAtom™ was providing was not meeting the needs of the teachers in the district, the company reflected on the challenges and worked with the assistance of district leadership to revise the approach. The district developed a network of teacher leaders, provided time for teachers to observe one another during the implementation, and made videos to offer additional support and training on the curriculum.

As was the case in this study, Guskey (1985) found that successful implementation and teacher transformation requires teachers to receive regular feedback on student outcomes to ensure new practices will not be abandoned. Teachers reported becoming more invested in the program and changing their own practices upon seeing student growth in the classroom and on external accountability measures. As was reported in previous chapters, the participants' students were regularly assessed for accountability purposes through the MAP (measures of academic performance) testing and the MCAS (Massachusetts Comprehensive Assessment System). Additionally, participating teachers gave quizzes and tests to assess student comprehension and inform future instruction. In order to strengthen student understanding and depth of knowledge, teachers held student-led Socratic seminars, where students systematically examined scientific concepts and discussed texts, while deepening knowledge and gaining experience with academic discourse. Through these open forums, teachers were able to hear any misconceptions and guide students toward a solid understanding of concepts. Moreover, the teachers indicated that students built on their knowledge and modeled understanding during investigations and lab activities.

Finally, Guskey (1985) found that continued support and follow-up are necessary after initial training. A network of teacher leaders, the Science Champs, was created to provide additional ongoing support within the school setting. Furthermore, this finding aligns with Liker & Meier's (2007), validating the assertion that professional development, removed from the setting where teachers work, can lead to superficial learning but not real change.

Much of the traditional PD focuses on initiating change in the beliefs, attitudes, and perceptions of teachers, whereas Guskey's (1985) model posits that those changes do not come until after there have been significant changes to student learning outcomes. Participating teachers and their colleagues were given in-depth initial training during the initiation phase, as well as follow-up training during the implementation phase. They were also offered time to view other, more experienced teachers, known as Science Champs, implementing the curriculum in the classroom. Finally, teachers were provided coaches to come observe their practices and give them technical feedback and in-class assistance on implementing the change in their classroom. The data and analysis from this study led the researcher to view teachers changes in practice through an adaptation of Guskey's (1985) model. In essence, Guskey's (1985) model should be seen not as a linear model, because change is ongoing learning and therefore a dynamic process. Each stage is dependent on other stages.

Guskey's model does not reflect the interconnected nature of the process of change. It also does not reflect the ongoing feedback teachers need to receive about their students' learning outcomes, nor does it reflect the continued support and follow-up necessary after initial training. The researcher would therefore like to propose an adaptation of Guskey's (1985) *Model of Teacher Change* and connect it back to Lewin's (1947) *Change as Three Steps (CATS) Model* and forward to Fullan's (2007) *Educational Change Theory*.

Lewin's unfreeze phase correlates with Guskey's PD phase in what Fullan would describe as the initiator of the change. Lewin's change phase correlates to Guskey's change in teaching practices during Fullan's implementation phase. Finally, Lewin's refreeze phase correlates with the changes in the teachers' beliefs and attitudes, which Fullan refers to as solidifying and institutionalizing the change. The change process is driven by student outcomes and ongoing support in the form of time, resources, and organization capacity. Viewing and analyzing the data through an interconnected lens helped the researcher better understand the teaching change process. A visual model of this interconnectedness can be seen in the following diagram.

Figure 7: A combination of Lewin's (1947), Guskey's (1985), and Fullan's (2007) models.

Teaching Practices

The teachers in this study were fourth and fifth grade science teachers. In order to address students' questions and misconceptions, the teachers needed background knowledge of the different domains of science. While adapting to changing science standards by implementing a new curriculum, the NGSS call for teachers to learn not only disciplinary core ideas, but also crosscutting concepts and science and engineering practices. With the adoption of the NGSS-inspired MA Science Frameworks, teachers not only had to gain a deeper understanding of the material, but they also had to learn how to apply best practices for enabling students to read the texts and write about what they were learning.

Guskey (2002) found that in order for new programs to be implemented well, it must become a natural part of teachers' teaching skills. The teacher participants in this study made a variety of shifts in their instructional practices. First, the teachers released the responsibility of providing all the information in the classroom. Participating teachers gave up some control of their classroom and assumed the role of a facilitator. Teachers did this by spending less time lecturing and instead facilitating Socratic dialogue, allowing students to discover concepts through discussion with their peers.

Second, teachers found ways to differentiate instruction to help students access the curriculum. One way teachers did this was by setting up labs and investigations, which students moved through at their own pace while developing habits of mind. Moreover, teachers allowed for more than one "right" answer during lab investigations or engineering design challenges. To provide scaffolds for English language learners, teacher participants pre-taught the science unit vocabulary and provided visuals and realia to offer continued support.

Third, teachers chose to hold all students to a higher standards. While this does seem self-evident, a majority of the teachers in this study reported viewing a student's capacity through the lens of the student being part of an urban, low-income, mostly minority population, who bring with them a history of trauma and speak a language other than English at home. They gauged their expectations on what they believed their students could do with their obstacles instead of believing that all students can achieve a high standard, though some will need additional supports and scaffolds to do so. Five of my study participants, discussed having lower expectations of students and being both shocked and amazed when they stuck to the grade-level curriculum. They reported their students continually surprising them at what they could accomplish when the level of expectation was raised.

Teachers raised the level of expectations by incorporating the use of non-fiction texts, which bolstered students' understanding of concepts. Additionally, teachers introduced vocabulary in context and connected to authentic examples. Teachers provided purposeful content alignment, expecting students to model instead of merely recalled information. Furthermore, teachers expected students to record their conclusions in writing in the students' lab notebooks, whereas there was little writing in science class before the curriculum implementation. Finally, teachers gave assessments that were more open-ended, asking students to explain their understanding of a concept in paragraph form.

Guskey (1985) proposed that changes in practice will stick only if the teacher saw positive student outcomes. Guskey's model broadly construed student outcomes to include "not only cognitive and achievement indexes, but also the wide range of student affective characteristics" (1985, p. 7).

Student Outcomes

Guskey (1985) gave a broadened definition of student learning outcomes as including whatever evidence the teachers use to judge the effectiveness of their teaching. Learner-centered teaching shifts the focus of activity from the teachers to the learners, giving students more control over the learning process. Teachers in this study found that having a learning-centered classroom increased student accountability to their peers and subsequently improved student participation and engagement in class discussions and lab activities. As students were given more opportunities to work together, participants shared witnessing enhanced student collaboration skills. Through the structured, student-led class discussions, the study suggests enriched interpersonal communication skills through the implementation of accountable talk. The study's findings also indicate that heightened engagement resulted in improved classroom behavior and better outcomes for all students, including large numbers of ELLs. The study's participants reported that these positive changes in the classroom have led them to reconsider their beliefs about what their students are able to accomplish.

Beliefs and Attitudes

According to Guskey (1985), changes in a teacher's attitudes and beliefs come from what they experience in the classroom. If teachers are not seeing positive outcomes in their students, they will be resistant to the change in order to maintain equilibrium (Henry, 1997). Teachers must be shown a truth that influences their feelings (Kotter & Cohen, 2002). While any new curriculum change brings with it a set of challenges, teachers in this study have had many positive student outcomes and have come to accept, and even embrace, the change. Additionally, these findings imply that positive student outcomes encouraged the teachers to change their beliefs about how science should be taught as well as their attitudes their students' abilities. Four key changes in attitudes and beliefs were discovered among the study participants and will now be discussed further.

First, teachers reported seeing how well science aligns with other core subjects. There are clear connections between science, English language arts and literacy, and mathematics. Teachers reported noticing that the nonfiction readers improved students' science background and academic vocabulary, especially for ELLs. Additionally, teachers expressed seeing an improvement in their students' ability to analyze texts and pull out main ideas. Teachers also described seeing the value of incorporating reading and writing skills in science, preparing students to write academic summaries. The crosscutting concepts, one of the three dimensions of the NGSS, connected concepts from mathematics such as patterns, scale, proportion, and quantity together with science. Teachers reported observing their students applying these cross-curricular skills and improving across the academic spectrum.

Second, the teachers noted the impact of student collaboration. Research shows that student learning and development are facilitated when students engage in progressively more complex material and learning tasks (Brofenbrenner, 1979; NGSS Lead States, 2013). Therefore, it is not only important for science to be taught at all grade levels, but it is also important for students to learn from and with each other. This study emphasized various benefits to collaborative learning.

Third, the teachers in this study reported finding value in releasing responsibility and sharing power with the students. The findings also imply that by shifting locus of control from teachers to students, students are more invested in learning outcomes and exercise greater control over behavior. In addition, they were reported to be more likely to do well academically and achieve at higher levels when teachers hold high expectations of students and empower them (Pintrich, 2003). The NGSS demands that teachers shift the balance of power from teachers to students, where the teacher's role is to facilitate the students discovery of concepts through engaging in meaningful tasks. In a learner-centered classroom, power is shared with students in amounts proportional to the students' abilities.

Finally, the teacher participants noted the importance of high expectations of all students. As the research suggests (National Research Council, 2012) and this study validates, when held to a higher standards of achievement, most students rise to the occasion when supplied with appropriate scaffolding. In this research, teachers reported observing the achievement gap closing, in part due to their higher expectations of student leadership, independence, and behavior. It is important to note that the NGSS set high expectations for all students, not just those planning to pursue STEM careers. Students are now being asked to do more than just recall information; they are now being asked to apply the information to real-world situations. Knowledge and skills are no longer separated. As participants witnessed their students rising to the new challenges of the NGSS, they shared that their beliefs about what students are capable of have changed also.

Implications for Practice

The following section discusses the implications of these findings on teacher practice, teacher training, and professional development. The findings suggest that teachers need authentic professional development and support in the form of time and resources. Moreover, it points to the need for teachers to be adaptable, patient, and faithfully implement the curriculum during the change process. Finally, teacher leaders were an important component of making the implementation of KnowAtom™ successful and, therefore, school leadership needs to invest in continually developing teacher leaders.

Teachers Need PD to be Embedded in Practice

Through the change process of implementing a new NGSS-aligned science curriculum, there was strong feedback from the teachers about the importance of authentic professional development that was embedded in practice and supported by the teacher leader network. The district initially had representatives from KnowAtom™ come and give a lecture-based overview of how the curriculum worked. Teachers expressed that a didactic approach to PD with theoretical information had very little practical use to them, especially when they were not familiar with the curriculum yet. The findings also suggest the importance of customizing professional development and curriculum training with the assistance of teachers as well as customizing for different levels of implementation with different school foci.

The findings also imply the importance of building a sustainable culture of teacher trainers and leaders when implementing a new curriculum. This was realized with the assistance of district leadership and teachers collaborating to create the science champions network. This teacher-driven, school-based network included multiple opportunities for observation and peer feedback several times a year for those newly implementing KnowAtom™. The Science Champs delivered professional development, collected district-wide best practices, and shared district- and school-level learning with other science teachers in their schools. Additionally, the school worked with KnowAtom™ to create implementation exemplars, videotaping exemplary teachers and using these videos as models for professional development and discussion. Also embedded in these exemplars were close captions cuing where the teacher moves were in each part of the lesson. This allowed teachers to see the KnowAtom™ curriculum being delivered in an authentic way within their own district.

With the realization of the need for professional development of a more dynamic nature, the district developed plans to continuously improve the science training, making it not only inclusive of the supportive structures, but also making it more specific to teacher needs and responsive to teacher feedback. The district now aligns training to different grade bands, with a science champ from each grade level in each school as opposed to just one or two champs per school. The district is working to institutionalize this network planning for meetings several times during the year in three different grade level bands: kindergarten-second, third-fifth, and sixth-eighth. The district will also continue to work and learn best practices for implementing and training with KnowAtom™ to improve both program delivery and student outcomes.

Teachers Need Support

Another key implication for practice is that teachers need support through the change for paradigm-shifting to happen. The support reported in this study came from a combination of advocacy on behalf of teachers by the district partner, KnowAtom™, a committed district leader, and the development of a strong cadre of teacher leaders. The study also found the need of implementation support in the form of time and resources, too.

Evidence from research (Bettez, 2011; Tong, 2010) along with substantiation from this study supports that learning communities can enhance teacher experiences during change. Lalor and Abawi (2014) indicated professional learning communities work more effectively when they are “timetabled, prioritized by school administration… [and have been] negotiated with all stakeholders involved” (p. 77). All of the teacher participants mentioned that having support either from the administration, the Science Champs, or another science professional learning community assisted them through the change process. Professional learning communities are centered around specific contexts and workplaces, and groupings can be made by interest, project, grade level, subject matter, among other contexts. The district recently made changes to the groupings of its Science Champions PLC, dividing the groups by grade level bands. Similar to findings from this study, Hord (2003) found that learning communities encompass many benefits, including collegial support and stronger professional connections, as well as increased levels of teacher job satisfaction and commitment.

Teachers need time. While the district provided time for teachers to be released from instruction to attend the Science Champs meetings or do observations of other teachers’ practices, the teachers in this study reported that time was still a constraint in trying to collaborate with other teachers. Some of the individual schools provided training and support during after-school hours, but this was also when some teachers led after-school programs. Other teachers described having time to meet within their subject teams, but expressed the desire to meet with teachers of other subjects like ELA/literacy and mathematics to enhance cross-curricular connections. Teachers reported needing time with the students to provide access to content. Teachers indicated that mathematics and ELA/literacy interventions used to happen during science, but that has started to change. They also specified that during testing times, their science class schedule was disrupted, which affected their planning and pacing.

Teachers need resources. Teacher participants described being appreciative of the high quality science supplies KnowAtom™ curriculum provides for the students. The teachers indicated that with the materials and technology, students were able to access the curriculum. Some of the teachers, who became Science Champs, described sharing resources across the district through a shared online folder.

Teachers Need to be Adaptable

As research (Parsons, Ankrum, & Morewood, 2016) suggests and this study supports, teachers must adjust their practices to different instructional situations. Guskey (2002) wrote that teaching requires improvisation, and Ball and Cohen (1999) added that teachers must be able to adapt their practice.

The teachers in this study expressed a variety of adaptations they had to make throughout the implementation of KnowAtom™. The data collected during interviews with teacher participants in this study documented the teachers' struggle with releasing responsibility to their students. All of the teacher participants described adapting the way they delivered instruction, shifting into the role of a facilitator during class discussions, lab investigations, and activities.

With both planned events like testing, and unplanned events like snow days, teachers conveyed the need to be adaptable with the pacing of the curriculum. Additionally, teachers explained that they had to adapt their instruction to meet the needs of their students. With a large ELL population, the teachers described pre-teaching vocabulary and reviewing concepts during the reading of the non-fiction texts. Spending extra time on scaffolding meant teachers had to adapt the pacing of the units.

Teacher Leaders are Important

Guskey (2002) found that teachers need continued support and follow-up after initial training on a curriculum change. A key finding from this study was the role teacher leaders play in a change process. The district created a team of teacher leaders, which it referred to as its Science Champions. Each of the participants in this study referenced the importance of teacher leaders as a key component of their success through the implementation phase. Some of the participants were nominated as Science Champions, whereas others turned to their school's Science Champion when they needed extra support.

Limitations and Recommendations for Future Research

This qualitative case study set out to explore changes in teaching practices as a result of the new Next Generation Science Standards. This study was limited by several things. First, the conceptual framework that provided the lens for the study limited the findings to those seen through the lens of the process of teacher change. Future research could view changes in teaching practices through a different theoretical or conceptual framework.

Second, the findings of the study may only be transferable to states and school districts, that have implemented the Next Generation Science Standards or an experiential, learner-centered curriculum like KnowAtom™. To be able to generalize the findings, there is a need to view the curriculum in various settings.

Third, the case study approach emphasized looking at a phenomenon within its own setting. The setting in this study was an urban school district in Massachusetts and may have its own nuances and idiosyncrasies. Future research could view changes in teaching practices with a broader population.

Fourth, there was a small number of participants in this study, which could have eliminated additional perspectives from more participants. Participants also self-selected into the study, so the characteristics of those who opted out and their experiences have not been included, leading to the potential for bias. Future research could include a broader population and perhaps use a methodology where teachers are randomly sampled and selected for participation in a more quantitative manner.

Finally, the teacher participants in this study attributed much of the implementation success to the teacher leaders, termed *Science Champs*. It might be helpful to explore the implementation of KnowAtom™ in school districts with and without science coaches to look closer at the implied effects of the Science Champs' role in successful outcomes for teachers and students.

Conclusion

The Next Generation Science Standards represent a significant shift from the way previous science standards have been written. Students are no longer expected to merely recall abstract facts, but are asked to demonstrate proficiency in the science processes and practices used to create new knowledge. In order to prepare students to meet this requirement, science teachers have had to also make significant changes in their teaching practices.

Instead of focusing on covering a large amount of content, teachers can now focus on teaching core ideas, which are ideas that have broad importance within or across science or engineering disciplines. Also, teachers will need to do less direct instruction and rather assume the role of coach or facilitator in the learning process. Because the concepts build coherently across K-12, hands-on science needs to be part of every grade level. To help students learn to think critically and assume more responsibility for their learning, teachers will need to create an environment of questioning, allowing students to struggle alongside their peers to find answers to their questions, knowing there is not always one "right" answer. Assessment should take place authentically and provide varied and multiple opportunities for students to show proficiency. With the NGSS's natural connections to the Common Core State Standards for reading and mathematics, students need to be doing more reading and writing in the science classroom.

The changes in instructional practices for this study's teacher participants have produced positive learning outcomes for students. Hands-on learning increased collaboration and communication skills, as well as student engagement. Increased participation resulted in better behavior and better test scores. These outcomes were a direct result of teaching adjusting their view of student capacity and choosing to hold students to a high standard of learning.

To prepare teachers for making the changes to their instruction, the district had to adapt its professional development delivery to make it more practical to the teachers. This study found that the implementation of the KnowAtom™ curriculum stalled until the district provided professional development that was embedded in practice and supported by ongoing social structures, including the district-level teacher leader network and school-level professional learning communities. Through announced and unannounced class observations by these support groups, combined with supportive feedback, teachers were guided to implement the curriculum with fidelity and improve their practices.

The NGSS have already been adopted by nineteen states, representing almost 40% of the U.S. public school population at the time of this study. More states are looking to adopt the standards or have implemented similar science standards already. With these major shifts in expectations of students, science teachers will be faced with the need to modify the way they deliver science instruction. This study highlighted the elements of a successful change implementation as well as some initial barriers to building teacher trust and buy in to a 21^{st} century-aligned pedagogy that will prepare the workforce of tomorrow.

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Appendix A: IRB Approval

Northeastern

Notification of IRB Action

Date: May 21, 2018	IRB #: CPS18-04-11
Principal Investigator(s):	Al McCready Tracy L. Waters
Department:	Doctor of Education College of Professional Studies
Address:	20 Belvidere Northeastern University
Title of Project:	The Effects of the Next Generation Science Standards (NGSS) on Teaching Practices: A KnowAtom Implementation Case Study
Participating Sites:	
Informed Consent:	Three (3) unsigned consents

Human Subject Research Protection
Mail Stop 560-177
360 Huntington Avenue
Boston, MA 02115
617.373.7570
fax 617.373.4595
northeastern.edu/hsrp

As per CFR 45 46.117(c)(2) signed consent is being *waived* as the research presents **no more than minimal risk** of harm to subjects and involves no procedures for which written consent is normally required.

DHHS Review Category:	Expedited #6, #7
Monitoring Interval:	12 months

Approval Expiration Date: MAY 20, 2019

Investigator's Responsibilities:

1. Informed consent form bearing the IRB approval stamp must be used when recruiting participants into the study.
2. The investigator must notify IRB **immediately** of unexpected adverse reactions, or new information that may alter our perception of the benefit-risk ratio.
3. Study procedures and files are subject to audit any time.
4. Any modifications of the protocol or the informed consent as the study progresses must be reviewed and approved by this committee **prior to being instituted.**
5. Continuing Review Approval for the proposal should be requested at least one month prior to the expiration date above.
6. This approval applies to the protection of human subjects only. It does not apply to any other university approvals that may be necessary.

C. Randall Colvin, Ph.D., Chair
Northeastern University Institutional Review Board

Nan C. Regina, Director
Human Subject Research Protection

Northeastern University FWA #4630

Appendix B: Teacher Recruitment Letter

Month Day, 2018
Dear Science Teacher:

For my Doctor of Education degree at Northeastern University, I am conducting a research study entitled *The Effects of the NGSS on Teaching Practices: An Instrumental Case Study* and, as this title suggests, I am examining the effect of the Next Generation Science Standards (NGSS) on teaching practice at the upper elementary school level.

As you know, the Massachusetts frameworks were designed based on the NGSS, which asks teachers to change their practice from teacher-directed to student-directed. You have implemented units and projects that fit this description.

Participation in the study will require an interview of teacher-participants, which will last approximately 45 minutes. This interview will take place on campus during a non-instructional period. After the interview, you will be provided with a transcription of the interview. A follow-up interview, either in person or by phone, will be scheduled for you to confirm the details of the transcript. It should last approximately 10-15 minutes.

The results of this study may be published in scientific research journals or presented at professional conferences. However, your name and identity will not be revealed and your record will remain confidential. To protect the identity of participants, I will use pseudonyms when referring to specific teachers.

Participation in this study may benefit school leaders, curriculum designers, and teachers by providing insight into the changes in practice science teachers are having to make to meet the new standards. You can choose not to participate. If you decide not to participate, there will not be a penalty to you or loss of any benefits to which you are otherwise entitled. You may withdraw from this study at any time.

If you choose to participate in this study, you will need to sign a consent form (attached) after we discuss this research in further detail and email it back to the researcher at this email address.

Additionally, if you wish to volunteer for this study, please email your responses to the following questions:

Please tell me about your teaching experience.

1. How many years have you been teaching?
2. What grade levels have you taught?
3. What was your major in your undergraduate and/or graduate programs?
4. What is the best aspect of teaching?
5. What is the most stressful aspect of teaching?

Can you tell me about your teacher preparation program?

1. What activities did you do to help prepare you to become a science teacher?
2. To what extent were the activities geared towards hands-on student learning?

If you have questions about this research study, you can contact me at (###)-###-#### or the Principal Investigator, Dr. Al McCready at (###)-###-####.

Sincerely,
Tracy L. Waters
Doctoral Candidate, Student Researcher
Northeastern University, College of Professional Studies

Appendix C: Teacher Consent

Signed Informed Consent Document – Teacher/ Northeastern University, Department: College of Professional Studies

Name of Investigator(s): Dr. Al McCready (Principal Investigator), Tracy L. Waters (Student Researcher)

Title of Project: *The Effects of the NGSS on Teaching Practices: An Instrumental Case Study*

Informed Consent to Participate in a Research Study

We are inviting you to take part in a doctoral research study. This form will provide you with information about the study. Additionally, the student researcher will explain it to you. You may ask the student researcher any questions you have. You do not have to participate in this study. If you decide to participate, please sign this document. The researcher will make a copy for you to keep.

Why am I being asked to take part in this research study?
You are being asked to participate in this study because you are a fourth or fifth grade science teacher who has used KnowAtom in your classroom for at least two years.

Why is this research study being done?
The purpose of this study is to learn about the impact of the Next Generation Science Standards on science teaching practice.

Who will be using and disclosing information about me?
The primary investigator and student researcher will be using information about your teaching experiences, but will refer to you with a pseudonym. Your personal information will be kept private and confidential and not used in any way.

What will I be asked to do?
If you participate in the study, you will be asked to take part in an interview in which you will be asked 5-8 open ended questions about your experience teaching a KnowAtom unit of study with some follow-up questions. There will be a follow-up in-person or phone interview for me to verify interview details after you have been given a copy of the transcript.

Where will this take place and how much of my time will it take?
The interview will last approximately 45 minutes, and take place during a non-instructional period at an agreed upon location. The follow-up interview would take place either in-person or by phone for your convenience and would last approximately 15 minutes.

Will there be any risk or discomfort to me?
There is no foreseeable risk or discomfort to participants.

Will I benefit by being in this research?
You will not directly benefit from this study, but the information learned as a result of this study could help teachers and school leaders to determine the kind and quality of science education that will most benefit their students in response to the new science standards. It could also provide more data for states that are considering adoption of the standards.

Who will see the information about me?
Participants' role in this study will remain confidential. Only the researchers of this study will see the information gathered during data collection. No reports or publications will use information that can identify participants in any way, or any individual as being part of this project.
The interview will be recorded using an electronic recorder for later transcription. This recording will be maintained for a period of six months, while the researcher is compiling and analyzing data and writing up her findings. The recording will be transcribed by a third party and will be sent to the third party with a pseudonym to maintain confidentiality. During this process, the recorder will remain at the student-researcher's place of residence, under lock and key. Once this process has been completed, the data will be erased from the device as further protection to the participants.

If I do not want to take part in the study, what choices do I have?
Participation in the study is completely voluntary. There is no penalty for not participating.

What will happen if I suffer any harm from this research?
There is no foreseeable harm to any participants in this study.

Can I stop my participation in this study?
Your participation in this research is completely voluntary. Even if you consent, you can stop participating at any time, and you can refuse to answer any question you are not comfortable with. If you decline to participate, or decide to quit, no rights, benefits, or services will be lost.

Who can I contact if I have questions or problems?
If you have questions or concerns regarding this study, please contact:
Tracy L. Waters, Student Researcher (###)-###-#### or
Dr. Al McCready, Principal Investigator (###)-###-####

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, 490 Renaissance Park, Northeastern University, Boston, MA 02115. Tel: (###)-###-####, Email: XXXX. Please reference IRB# CPS18-04-11. You may call anonymously if you wish.

Will I be paid for my participation?
No. There will be no remuneration for participation in this study.

Will it cost me anything to participate?
No. There are no costs associated with 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 D: Teacher Interview Protocol

Topic: *The Effects of the NGSS on Teaching Practices: An Instrumental Case Study*

Time of interview:
Date:
Place:
Interviewer: Tracy L. Waters
Interviewee #:

Introduction

As you know, I am in my final phase of my doctoral program and your help today will aid me in completing this journey, so I want to thank you for your time. This research project focuses on how fourth and fifth grade science teachers have had to change their practices when implementing KnowAtom. The hope is that this research can be used to help other science teachers, who are having to change their practices to meet the demands of the Next Generation Science Standards, as well as curriculum decision makers, who are having to choose materials aligned to the NGSS.

First, I want to emphasize that all of my participants will remain anonymous, and that your participation is completely voluntary. If you don't mind, I would like to review the consent form with you before we begin.

[Review and sign NEU Consent Forms]

Thank you. I have a few more administrative items to discuss before we begin. Since your responses are important and I want to make sure to capture everything you say, I would like to audio record our conversation today so I can replay it after to analyze. Is that okay? Also, I will have a professional transcriptionist to transcribe the interviews. The transcriptionist will receive the audio labeled by a pseudonym, meaning they will never know your name to maintain confidentiality. Once the audio recording is transcribed, I will email you a copy for your review. Is that okay? Finally, I will forward you a copy of my overall findings soliciting your comments or corrections. How does that work for you?

I have planned for this interview to last no longer than 45 minutes. During this time, I have several questions that I would like to cover. Therefore, it may be necessary to interrupt you in order to push ahead and complete the line of questioning. Additionally, there may be times where I may prompt you to go deeper in your explanations. Do you have any questions before we start?

[Turn on Recorder]

Let's begin.

<u>Interview Questions</u>

Prompts to be used during interview

· *Can you tell me more about that?*
· *Can you provide an example?*
· *Can you provide any documentation I can take with me?*

I am now going to ask you questions focused on the topic of the study, which is how you have changed your teaching practice for the Next Generation Science Standards (NGSS). I will be exploring your perspectives on professional development, changes in teaching practice, changes in student outcomes, and changes in your attitude or beliefs since implementing the KnowAtom curriculum.

1. *Can you describe how you initially felt about implementing the KnowAtom curriculum?*
2. *Can you tell me about the professional development you were provided for KnowAtom?*
    a. *Can you describe your first professional development (PD) with KnowAtom?*
    b. *How long did it last?*
    c. *Was it before or after you implemented the KnowAtom program?*
    d. *How did you feel about implementation after the PD?*
    e. *Can you tell me about some of the strategies you learned from the KnowAtom PD?*
3. *Can you tell me about your teaching practice before KnowAtom?*
    a. *Can you describe for me a typical science class/unit before KnowAtom?*
    b. *How much time did you spend lecturing versus facilitating activities?*
    c. *Were your labs and activities different before implementing KnowAtom?*
        i. *If so, in what way?*
        ii. *If not, how were they similar?*
4. *Can you describe how your teaching practice has changed since implementing KnowAtom?*
    a. *What supports helped you make these changes?*
    b. *Was there anything that hindered you from making changes? (i.e. time, access to technology, supplies, etc.)*
    c. *How are the new NGSS-inspired standards different from the previous MA Frameworks?*

For the purpose of this study, student outcomes are defined as any type of outcome (e.g., increased attendance, engagement, participation, etc.)

5. *Have you noticed ANY student outcomes in students that are different from previous behaviors since implementing KnowAtom and, if so, could you share with me what you have noticed?*
    a. *Can you describe for me how the student outcomes you mentioned impact your instructional environment?*
    b. *Can you describe for me how student outcomes you mentioned impact your classroom culture?*
6. *Can you describe how your overall feelings (attitudes/beliefs) have changed since implementing KnowAtom?*

   a. *What is it about the curriculum that makes you feel that way?*
   b. *Can you describe how the KnowAtom curriculum prepares students for the MCAS?*

7. *Is there anything else about your teaching experience/teaching practice since implementing KnowAtom that you would like to share?*

Thank you for your cooperation and participation in this interview. Just a reminder, your responses will be tied to a pseudonym and therefore your identity will be confidential.

If I come across a need to ask any follow-up questions, which would most likely only be the case if I felt clarification were needed in regard to one of your responses, would it be all right for me to contact you? Would you prefer I contact you via email or telephone?

Sometime over the next month, I will email you word-for-word transcripts. If you choose, you can review the information, and you will have one week to provide me with any feedback, alterations, or corrections. Can you please confirm the email address you would like for me to email the transcripts to?

Finally, when this thesis study is complete, which will most likely be 3-6 months from now, would you like to receive an electronic copy of the document?

Do you have any questions for me?

Thank you so much for your participation in this study!

IRB# CPS18-04-11

Approved: 5/21/18

Expiration Date: 5/20/19

Appendix E: School Administrator Recruitment Letter

Month Day, 2018
Dear School Administrator:

For my Doctor of Education degree at Northeastern University, I am conducting a research study entitled *The Effects of the NGSS on Teaching Practices: An Instrumental Case Study*, and as this title suggests, I am examining the effect of the Next Generation Science Standards (NGSS) on teaching practice at the upper elementary school level.

As you know, the Massachusetts frameworks were designed based on the NGSS, which asks teachers to change their practice from teacher-directed to student-directed. You are an administrator of a school that has implemented the KnowAtom curriculum.

Participation in the study will require an interview of administration-participants, which will last approximately 45 minutes. This interview will take place on campus during a mutually agreed upon time and place. After the interview, you will be provided with a transcription of the interview. A follow-up interview, either in person or by phone, will be scheduled for you to confirm the details of the transcript. It should last approximately 10-15 minutes.

The results of this study may be published in scientific research journals or presented at professional conferences. However, your name and identity will not be revealed and your record will remain confidential. To protect the identity of participants, I will use pseudonyms when referring to specific teachers.

Participation in this study may benefit other science teachers by providing insight into the changes in practice science teachers are having to make to meet the new standards. It may also benefit school leaders, curriculum designers, and states looking to adopt the NGSS. You can choose not to participate. If you decide not to participate, there will not be a penalty to you or loss of any benefits to which you are otherwise entitled. You may withdraw from this study at any time.

If you choose to participate in this study, you will need to sign a consent form after we discuss this research in further detail and email back to the researcher at this email address: waters.t@husky.neu.edu.

Additionally, if you wish to volunteer for this study, please email your response to the following questions:

Please tell me about your experience in education.

1. How long have you been an administrator?
2. Before becoming an administrator, what subjects and grade levels have you taught?
3. What was your major in your undergraduate and graduate programs?
4. What was the best aspect of teaching?

5. What was the most stressful aspect of teaching?

If you have questions about this research study, you can contact me at (###)-###-#### /waters.t@husky.neu.edu, or the Principal Investigator, Dr. Al McCready, at (###)-###-####.

You will not be contacted again regarding this research.

Sincerely,
Tracy L. Waters
Doctoral Candidate, Student Researcher
Northeastern University, College of Professional Studies

IRB# CPS18-04-11

Approved: 5/21/18

Expiration Date: 5/20/19

Appendix F: School Administrator Interview Protocol

Topic: *The Effects of the NGSS on Teaching Practices: An Instrumental Case Study*

Time of interview:
Date:
Place:
Interviewer: Tracy L. Waters
Interviewee #:

Introduction

As you know, I am in my final phase of my doctoral program and your help today will aid me in completing this journey, so I want to thank you for your time. This research project focuses on how fourth and fifth grade science teachers have had to change their practices when implementing KnowAtom. The hope is that this research can be used to help other science teachers, who are having to change their practices to meet the demands of the Next Generation Science Standards, as well as curriculum decision makers, who are having to choose materials aligned to the NGSS.

First, I want to emphasize that all of my participants will remain anonymous, and that your participation is completely voluntary. If you don't mind, I would like to review the consent form *with you before we begin.*

[Review and sign NEU Consent Forms]

Thank you. I have a few more administrative items to discuss before we begin. Since your responses are important and I want to make sure to capture everything you say, I would like to audio record our conversation today so I can replay it after to analyze. Is that okay? Also, I will have a professional transcriptionist to transcribe the interviews. The transcriptionist will receive the audio labeled by a pseudonym, meaning they will never know your name to maintain confidentiality. Once the audio recording is transcribed, I will email you a copy for your review. Is that okay? Finally, I will forward you a copy of my overall findings soliciting your comments or corrections. How does that work for you?

I have planned for this interview to last no longer than 45 minutes. During this time, I have several questions that I would like to cover. Therefore, it may be necessary to interrupt you in order to push ahead and complete the line of questioning. Additionally, there may be times where I may prompt you to go deeper in your explanations. Do you have any questions before we start?

[Turn on Recorder]

Let's begin.

<u>Interview Questions</u>

Prompts to be used during interview

· *Can you tell me more about that?*
· *Can you provide an example?*
· *Can you provide any documentation I can take with me?*

I am now going to ask you questions focused on the topic of the study, which is regarding the changes in teaching practices for the Next Generation Science Standards (NGSS). I will be exploring your perspectives on professional development, changes in teaching practice, changes in student outcomes, and changes in your attitude or beliefs since implementing the KnowAtom curriculum.

1. *How are the new NGSS-inspired standards different from the previous MA Frameworks?*
    a. *When did you first learn that science standards were changing?*
    b. *What steps did you take to address those changing standards?*
2. *What was it about the KnowAtom curriculum that made you decide to implement it in your district?*
    a. *Can you describe for me how you learned about KnowAtom?*
    b. *Can you describe how you initially felt about implementing the KnowAtom curriculum?*
3. *Were you or your teachers provided professional development (PD) by KnowAtom?*
    a. *How long did the PD last?*
    b. *Was it before or after you implemented the KnowAtom program?*
    c. *How did you feel about implementation after the PD?*
    d. *Can you tell me about some of the strategies you learned from the KnowAtom PD?*
4. *Can you describe for me a typical science class/unit before KnowAtom?*
    a. *How much time did the teachers spend lecturing versus facilitating activities?*
    b. *Were the labs and activities different before implementing KnowAtom?*
        i. *If so, in what way?*
        ii. *If not, how were they similar?*
5. *Can you describe for me what changes in the teachers' teaching practice has have you noticed since implementing KnowAtom?*
    a. *What supports helped them make these changes?*
    b. *Was there anything that hindered them from making changes? (i.e. time, access to technology, supplies, etc.)*

For the purpose of this study, student outcomes are defined as any type of outcome (e.g., increased attendance, engagement, participation, etc.)

6. *Have you noticed ANY student outcomes in students that are different from previous behaviors since implementing KnowAtom and, if so, could you share with me what you have noticed?*
    a. *Can you describe for me how the student outcomes you mentioned impact the classroom instructional environment?*

   b. *Can you describe for me how student outcomes you mentioned impact the classroom culture?*
7. *Can you describe how your overall feelings (attitudes/beliefs) toward instruction have changed since implementing KnowAtom?*
   a. *What is it about the curriculum that makes you feel that way?*
   b. *Can you describe how the KnowAtom curriculum prepares students for the MCAS?*
8. *Is there anything else about your experience since implementing KnowAtom that you would like to share?*

Thank you for your cooperation and participation in this interview. Just a reminder, your responses will be tied to a pseudonym and therefore your identity will be confidential.

If I come across a need to ask any follow-up questions, which would most likely only be the case if I felt clarification were needed in regard to one of your responses, would it be all right for me to contact you? Would you prefer I contact you via email or telephone?

Sometime over the next month, I will email you word-for-word transcripts. If you choose, you can review the information, and you will have one week to provide me with any feedback, alterations, or corrections. Can you please confirm the email address you would like for me to email the transcripts to?

Finally, when this thesis study is complete, which will most likely be 3-6 months from now, would you like to receive an electronic copy of the document?

Do you have any questions for me?

Thank you so much for your participation in this study!

IRB# CPS18-04-11

Approved: 5/21/18

Expiration Date: 5/20/19

Appendix G: KnowAtom Employee Recruitment Letter

Month Day, 2018
Dear Mr. Vigeant:

For my Doctor of Education degree at Northeastern University, I am conducting a research study entitled *The Effects of the NGSS on Teaching Practices: An Instrumental Case Study,* and as this title suggests, I am examining the effect of the Next Generation Science Standards (NGSS) on teaching practice at the upper elementary school level.

As you know, the Massachusetts frameworks were designed based on the NGSS, which ask teachers to change their practice from teacher-directed to student-directed. You work for KnowAtom and are familiar with the curriculum.

Participation in the study will require an interview, which will last approximately 45 minutes. This interview will take place at a mutually agreed upon place and time. After the interview, you will be provided with a transcription of the interview. A follow-up interview, either in person or by phone, will be scheduled for you to confirm the details of the transcript. It should last approximately 10-15 minutes.

The results of this study may be published in scientific research journals or presented at professional conferences. However, your name and identity will not be revealed, unless you give consent for it to be. If you do choose to remain anonymous, your record will be kept confidential and pseudonyms will be used when referring to you.

Participation in this study may benefit other science teachers by providing insight into the changes in practice science teachers are having to make to meet the new standards. It may also benefit school leaders, curriculum designers, and states looking to adopt the NGSS. You can choose not to participate. If you decide not to participate, there will not be a penalty to you or loss of any benefits to which you are otherwise entitled. You may withdraw from this study at any time.

If you choose to participate in this study, you will need to sign a consent form after we discuss this research in further detail and email back to the researcher at this email address: waters.t@husky.neu.edu.

Additionally, if you wish to volunteer for this study, please email your response to the following questions:

Please tell me about your experience in education.

1. How long have you worked with KnowAtom?
2. Did you work in education before joining KnowAtom?
3. Were you ever a teacher? If so, what subjects and grade levels have you taught?

If you have questions about this research study, you can contact me at (###)-###-####, or the Principal Investigator, Dr. Al McCready, at (###)-###-####.

You will not be contacted again regarding this research.

Sincerely,
Tracy L. Waters

Doctoral Candidate, Student Researcher

Northeastern University, College of Professional Studies

IRB# CPS18-04-11

Approved: 5/21/18

Expiration Date: 5/20/19

Appendix H: KnowAtom Employee Interview Protocol

Topic: *The Effects of the NGSS on Teaching Practices: An Instrumental Case Study*

Time of interview:
Date:
Place:
Interviewer: Tracy L. Waters
Interviewee #:

<u>Introduction</u>

As you know, I am in my final phase of my doctoral program and your help today will aid me in completing this journey, so I want to thank you for your time. This research project focuses on how fourth and fifth grade science teachers have had to change their practices when implementing KnowAtom. The hope is that this research can be used to help other science teachers, who are having to change their practices to meet the demands of the Next Generation Science Standards, as well as curriculum decision makers, who are having to choose materials aligned to the NGSS.

First, I want to emphasize that you have agreed to have your identity revealed, but that your participation is completely voluntary. If you don't mind, I would like to review the consent form with you before we begin.

[Review and sign NEU Consent Forms]

Thank you. I have a few more administrative items to discuss before we begin. Since your responses are important and I want to make sure to capture everything you say, I would like to audio record our conversation today so I can replay it after to analyze. Is that okay? Also, I will have a professional transcriptionist to transcribe the interviews. The transcriptionist will receive the audio labeled by a pseudonym, meaning they will never know your name to maintain confidentiality. Once the audio recording is transcribed, I will email you a copy for your review. Is that okay? Finally, I will forward you a copy of my overall findings soliciting your comments or corrections. How does that work for you?

I have planned for this interview to last no longer than 45 minutes. During this time, I have several questions that I would like to cover. Therefore, it may be necessary to interrupt you in order to push ahead and complete the line of questioning. Additionally, there may be times where I may prompt you to go deeper in your explanations. Do you have any questions before we start?

[Turn on Recorder]

Let's begin.

Interview Questions

Prompts to be used during interview

- *Can you tell me more about that?*
- *Can you provide an example?*
- *Can you provide any documentation I can take with me?*

I am now going to ask you questions focused on the topic of the study, which is regarding the changes in teaching practices for the Next Generation Science Standards (NGSS) while using KnowAtom. I will be exploring your perspectives on professional development, changes in teaching practice, changes in student outcomes, and changes in attitude or beliefs with the KnowAtom curriculum.

1. *First, please tell me about the mission and vision of KnowAtom.*
    a. *What led you to work with KnowAtom?*
    b. *What was your major in your undergraduate and/or graduate programs?*
2. *How are the new NGSS-inspired standards different from the previous MA Frameworks?*
    a. *When did you first learn that science standards were changing?*
    b. *What steps did you take to address those changing standards?*
    c. *Can you describe how the KnowAtom curriculum prepares students for the MCAS?*
3. *Can you describe for me the professional development (PD) provided by KnowAtom to its clients?*
    a. *How long does the PD last?*
    b. *At which stage of implementation is the PD provided?*
4. *Can you describe for how science lessons are different with KnowAtom?*
    a. *How did you ensure alignment to the NGSS/MA Frameworks?*
5. *Do you ever do teacher observations?*
    a. *If so, can you describe for me what changes in the teachers' teaching practice has have you noticed since implementing KnowAtom?*
    b. *What supports helped them make these changes?*
    c. *Was there anything that hindered them from making changes? (i.e. time, access to technology, supplies, etc.)*

For the purpose of this study, student outcomes are defined as any type of outcome (e.g., increased attendance, engagement, participation, etc.)

6. *Are you aware of any changed student outcomes since implementing KnowAtom and, if so, could you share with me what you have noticed.*
    a. *How do you feel these outcomes affect the classroom environment or culture?*

Do you ever consult with teachers or administrators on their feelings toward KnowAtom?

7. *Can you describe to what extent you have noticed any changes in overall feelings (attitudes/beliefs) toward instruction after a school has implemented KnowAtom?*
8. *Is there anything else about KnowAtom that you would like to share?*

Thank you for your cooperation and participation in this interview. Just a reminder, your identity will be confidential, unless you choose to be identified, which you have agreed to.

If I come across a need to ask any follow-up questions, which would most likely only be the case if I felt clarification were needed in regard to one of your responses, would it be all right for me to contact you? Would you prefer I contact you via email or telephone?

Sometime over the next month, I will email you word-for-word transcripts. If you choose, you can review the information, and you will have one week to provide me with any feedback, alterations, or corrections. Can you please confirm the email address you would like for me to email the transcripts to?

Finally, when this thesis study is complete, which will most likely be 3-6 months from now, would you like to receive an electronic copy of the document?

Do you have any questions for me?

Thank you so much for your participation in this study!