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Experiencing the Implementation of New Inquiry Science Curricula

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EXPERIENCING THE IMPLEMENTATION OF NEW INQUIRY SCIENCE CURRICULA

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ABSTRACT

Using a phenomenological methodology, a cohort of four experienced science teachers was interviewed about their experience transitioning from traditional, teacher and fact-centered science curricula to inquiry-based curricula. Each teacher participated in two interviews that focused on their teaching backgrounds, their experience teaching the prior traditional curriculum, and their experience teaching the new inquiry-based curriculum. The findings are presented as a narrative of each teachers' experience with the new curriculum implementation. Analyzing the data revealed four key themes. 1) The teachers felt trapped by the old curriculum as it did not align with their positive views of teaching science through inquiry. 2) The teachers found a way to fit their beliefs and values into the old and new curriculum. This required changes to the curriculum. 3) The teachers attempted to make the science curriculum as meaningful as possible for their students. 4) The teachers experienced a balancing act between their beliefs and values and the various aspects of the curriculum. The revealed essence of the curriculum transition is one of freedom and reconciliation of their beliefs.

The teachers experienced the implementation of the new curriculum as a way to ensure their values and beliefs of science education were embedded therein. They treated the new curriculum as a malleable structure to impart their grander ideas of science education (e.g. providing important skills for future careers, creating a sense of wonder, future problem solving) to the students. Their changes were aligned with the philosophy of the curriculum kits they were implementing. Thus, the fidelity of the curriculum's philosophy was not at risk even though the curriculum kits were not taught as written.

This study showed that phenomenological methods are able to reveal the relationship between a teacher's prior experiences, values and beliefs and their current instructional philosophy in science education. An analytical diagram was developed based on this relationship and the teachers' experiences moving from a traditional to a new inquiry curricula. The diagram suggests a transition from feeling trapped in an existing curriculum that is inconsistent with teacher values to finding a fit and balance in a new curriculum that provides a better though not perfect fit. This diagram can serve as a guide for how to design future, ongoing professional development to ensure the success of an inquiry curriculum designed to replace a more traditional one and may be applicable to other teachers.

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Chapter 1:

Introduction

Education is subject to frequent reforms (Noddings, 2007) and science education is not immune to this (DeBoer, 1991). Dewey (1910, 1916) led the initial reform in US science education arguing that there was too much emphasis placed on learning the products of science at the expense of engaging in the process of science (i.e. the methods and means scientists use to do science). In later works, Dewey (1934) advocated for the role of science to develop democratic citizens. A democratic citizen was more than just someone who voted. A democratic citizen participated in a truly active community. He envisioned the wide dissemination of information between people, universities working closely with local schools, and students becoming active members, rather than passive members, of the community.

In order to prepare students as democratic citizens, Dewey believed students needed a way to develop their intelligence. Teachers could provide this to students by having them solve "the strategic problems that confront them from life to death" (Benson, Harkavy, & Puckett, 2007, p. 24). This problem solving must be "*reflective*, *strategic*, real-world problem-solving action and experience" (p. 25, original emphasis included). As a result, this type of problem solving can "function as the most powerful means to raise the level of instrumental intelligence in individuals, groups, communities, societies, and humanity" (p. 25). He believed that children were "naturally curious, eager to learn how to do things, and dynamically active" (p. 27). Utilizing this natural curiosity would allow educators to help develop students who would become active citizens.

Dewey's method of learning science as science is done is over a century old. Yet, much research finds that science education isn't about natural curiosity or exploring the environment. Instead, it is about fact memorization, applying ideas to already-solved problems, and performing experiments where the outcome is already known (Seethaler, 2009). The consequence of these fact-focused curricula and teacher-centered pedagogies is students who are unprepared to face modern challenges in today's society. The National Research Council [NRC] argued "many of the challenges that face humanity now and in the future…require social, political, and economic solutions that must be informed deeply by knowledge of the underlying science and engineering" (2012, p. 7).

An example of how tightly woven these challenges are with science can be seen during what Schiro (2009) identified as the catalyst for the first reformation in science education: the 1950s and 1960s space race. Mooney and Kirshenbaum (2009) discussed that the launch of the Soviet satellite Sputnik threatened the security, image, and general prosperity of the United States. By developing better science education curricula for our (then) students, at all levels, and investing in science research, "the knowledge produced would lead to technological advances that would enrich our lives—improving health and medicine, spurring economic growth and the creation of jobs, and strengthening the national defense" (Mooney & Kirshenbaum, 2009, p. 26).

Consequently, the National Defense Education Act was enacted which "provid[ed] generous funding to encourage American students to pursue careers in science and engineering," (p. 27). New science curricula were developed that focused on discovery (Mooney & Kirshenbaum, 2009) and updated outdated textbooks (Kahle, 2007). Those new curricula not only provided students with up-to-date information but also allowed the students to focus on “the methods of inquiry” and the importance of “individual judgment” (Kahle, 2007, p. 916). Even with great emphasis on reforming science education, little changed in how science was taught. Part of this is attributed to classroom teachers following standards and pacing guides (Buxton & Provenzo, 2011) and a greater focus on content knowledge (DeBoer, 2000) rather than embracing inquiry learning.

In the 1980s and 1990s a number of reports were published that criticized aspects of education, science included. These reports include, but are not limited to, the National Science Board’s (1983) *Educating Americans for the 21st Century* and the National Commission on Excellence in Education’s (1983) *A Nation at Risk*.

Reports like these are what fueled the standards development boom. However, the standards developed in most states did not reflect an inquiry or constructivist style of learning. Instead, the developed standards demoted science education to the memorization of facts and the application of knowledge to already known situations (Seethaller, 2009; Lerner, Goodenough, Lynch, Schwartz, & Schwartz, 2012). Buxton and Provenzo (2011) summarized that state standards developed in the 1980s and 1990s are “conceptualized as an attempt to promote knowledge of discrete science benchmarks loosely clustered into strands, plus the ability to perform some iteration of a ‘scientific method’” (p. 47).

In contrast, the American Association for the Advancement of Science’s [AAAS] (1989, 1990) *Science for All Americans* was the first to capture the essence of scientific literacy and provide benchmarks for learning objectives at different grade levels. The benchmarks have frequently been cited throughout literature as important to returning science education to its original roots of Deweyan ideals. However, these benchmarks are often ignored as a result of the era of modern assessment and accountability (Lerner et al., 2012).

The NRC (2012) called for students to be given the opportunity, via curricula, to respond to their previously mentioned challenges. And they are not alone in this call. The AAAS (1990) and several scientists, researchers, and educators (Allum, 2011; Baker, 2006; Miller 1998, etc.) share a common position with the NRC. The curricula they advocate for is intended to make students scientifically literate by the time they exit high school. This holds regardless of whether students are pursuing STEM (science, technology, engineering, or mathematic) careers or not.

Scientific Literacy

The purpose of science education is to create scientifically literate adults. Scientific literacy ensures adults will have the mental tools and skills necessary to participate in communities and handle the challenges—social, political, and economic issues—previously mentioned. The AAAS (1993) defined science literacy as requiring:

> [an] understanding and habits of mind that enable citizens to grasp what [science] enterprises are up to, to make some sense of how the natural and designed worlds work, to think critically and independently, to recognize and weigh alternative explanations of events and design trade-offs, and to deal sensibly with problems that involve evidence, numbers, patterns, logical arguments, and uncertainties (p. XI).

The AAAS further established that scientific literacy should last through adulthood. Scientific literacy is not something that should disappear once a student leaves the educational system.

Although the definition is rather detailed, it defines exactly what many science educators (Anderson, 2007; Lederman, 2007; Roberts, 2007) and scientists (Bramble, 2005; Hazen & Trefil, 2009; Seethaler, 2009) identified as problems with scientifically illiterate adults. Scientifically illiterate adults do not know how to examine or understand the natural world, understand arguments, nor identify poorly conducted studies and non-scientific studies that disguise themselves as scientific. It is estimated that "fewer than 7 percent of American adults can be classified as scientifically literate" (Hazen & Trefil, 2009, p. xv). These authors further claimed that fewer than 22% of college graduates and fewer than 26% of adults holding graduate degrees are considered scientifically literate.

The consequences of scientific illiteracy are grave: a nation whose own self-interest will be at stake through unaddressed environmental (e.g. global warming, pollution, over-mining and harvesting of natural resources) and human issues (e.g. population control, health issues, disease epidemics). When adults are not scientifically literate, their understanding of the issues prevents them from understanding why these issues are serious and it prevents them from understanding the consequences of letting these issues just go by (Hazen & Trefil, 2009; NRC, 2012; Seethaler, 2009). There are individuals, groups, and companies that gain financially from this illiteracy (Oreskes & Conway, 2010). They can manipulate or select data to make common occurrences seem worse than they are and make global emergencies a non-priority (Seethaler, 2009).

Scientific Literacy through Constructivism and Inquiry Learning

The academic literature reveals that the best way to overcome scientific illiteracy is through the use of constructivist and inquiry-based science curricula at all grade levels (AAAS, 1990; Lederman, 2007; Roberts 2007). These are in contrast to traditional science pedagogies and curricula: teachers providing direct instruction to students, a focus on the memorization of facts, implementation of predesigned experiments that require students reach a single, predetermined outcome, and doing activities that often engage students in simply being busy rather than in authentic scientific investigations. Constructivist pedagogies, in contrast, are grounded within a Piagetian frame of learning: one cannot learn by watching, one must learn by doing (Piaget, 1952). To Piaget, students learn based on their prior knowledge. Students do not learn because knowledge is out there; students learn because they create the knowledge through their experiences. When a student attempts to merge what they are experiencing with what they know, learning occurs.

Constructivism is closely connected with science because it is part of the scientific process through which scientists answer questions (Anderson, 1998). Constructivism sets the path for inquiry learning in the science classroom. Although constructivism and inquiry are closely intertwined, constructivism exists as an epistemology or theory for learning (Ültanir, 2012) and inquiry is a form of constructivism in action. Further, inquiry, as a term, is more readily applied to the nature of science, learning, and teaching more so than constructivism theory (Anderson, 2007).

Although there is no clear definition of inquiry when used in the context of science education (R. Anderson, 2002; C. Anderson, 2007), inquiry is often described as learning science as science is actually done (NRC, 1996). That is, inquiry encompasses the methods and modes of thinking scientists use in asking questions, designing investigations, and reaching their conclusions. Anderson (1998) defined inquiry as "the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work" (p. 23). The NRC (2000) is often cited for its delineated definition of inquiry. "Inquiry abilities," they noted, "require students to mesh these processes with scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science" (p. 18). This goes beyond having students learn basic science processes, such as observing and experimenting, and includes a more critical thinking orientation into the nature of science.

The promotion of inquiry in science classrooms is nothing new. As previously noted, Dewey advocated for inquiry in the early 1900s. The call for inquiry was renewed in the 1950s and 1960s due to the launch of the Soviet satellite Sputnik (DeBoer 1991; Hoff, 1999; Mooney & Kirshenbaum, 2009). In the 1990s, the AAAS (1993) stated the change from the fact-based curriculum to a problem-based curriculum would take the nation at least a decade due to the sheer size of the nation. Yet, that decade has come and gone and many of the nation's schools are still relying on fact-based curricula. Presently, the NRC (2012) has released an updated framework for teaching science in preparation for the Next Generation Science Standards (NGSS Lead States, 2013). The new nation-wide standards are grounded in inquiry practices and resituate learning science as a process versus digesting science as a body of content. These reforms in pedagogies and standards have been shown to be positive, yet teachers are disinclined to implement changes in their pedagogy (Keys and Brian, 2001)

Part of this reluctance is the implementation of high-stakes testing. Darling-Hammond (2010) commented on how schools will design curriculums that teach towards the standardized tests. Instead of learning a skill, students are taught to memorize, look for patterns, and work problems through teacher-prepared algorithms. “Schools,” she said “focus on the tested material in ways that narrow the curriculum and do not generalize to other situations or kinds of knowledge” (p. 283). Noddings (2007) warned of the limitations standards put on curriculums. She noted that standards and objectives narrow the curriculum. This shifts the purpose of the curriculum to memorizing countless, meaningless facts.

Exacerbating this is the lack of scientific backgrounds for science educators. Willingale-Theune et al. (2009, citing More, 2007) discussed how teachers who do not understand the processes involved in science have dominated science education. These teachers have little to no experience with the methodology of science. This lack of experience and understanding causes educators to rely on teacher-centered pedagogies. Part of this is attributed to their limited understanding of the nature of science, the “epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development” (Lederman, 2007, p. 833). Understanding the nature of science is an essential component to scientific literacy (Lederman, 2007). Aguirre, Haggerty, and Linder (1990) surveyed student-teachers’ conceptions of the nature of science. The student-teachers had varied conceptions of the nature of science. The authors concluded, “the holding of a positivistic-empiricist view of science by student-teachers may be a significant disposition leading them to subsequently adopt a ‘transmissive’ approach to teaching” (p. 389).

Bramble (2004), in a chapter discussing instruction of science to education and other non-science majors, demonstrated how her students did not have an understanding of the nature of science. She noted how students would select data to support their already pre-determined understanding. For example, she had her students read a research study on the freshman 15: a popular myth that students gain 15 pounds during their first year of college. The study found that there were no data to support freshman students gaining or losing a significant amount of weight. In fact, there was a small decrease in weight. Yet, many of her students still held on to the belief that the freshman 15 is true because "they had seen it for themselves" (p. 52).

In order to overcome this, Bramble stated "students' notions need to be challenged in a way that gets them uncomfortable with their pre-existing knowledge and allows them to reshape their understanding of the world" (p. 53). To do this she stated, "student understanding about the nature of science and scientific inquiry need to make them more critical purveyors of new information and more appreciative of the strengths and limits of science in society" (p. 53). Undergraduate science experiences are not allowing this to happen as evidenced by Hazen & Trefil's (2009) statement of adult scientific literacy.

Darling-Hammond (2010) discussed the role alternative certification programs and even traditional certification programs play in this problem. Alternative certification programs, she argued, are too short and do not allow the new educator to approach the curriculum with the expertise that is required. She stated that teachers who are prepared through alternative certification programs often "construct a teaching style that focuses on control…by 'dumbing down' the curriculum to what can easily be managed" (p. 48).

In a comparative study between pre-service teachers—those preparing to teach—and in-service teachers—active teachers—Hoh (2013) found that in-service teachers held an understanding of science more consistent with the nature of science than pre-service teachers. She speculated, "pre-service teachers…are still heavily influenced by their structured formal education" (p. 34), implying that the pre-service teachers have limited, authentic scientific experiences during their college careers. Her speculation is supported by several other studies, as reviewed by Lederman (2007), which found that teachers' experiences (limited or not) in learning and working within the nature of science influence their understanding of the nature of science. However, this is not to imply that more experience with science necessarily increases one's understanding of the nature of science. Aguirre, Haggerty, and Linder (1990), conducted a case study of pre-service science teachers' conceptions of the nature of science. These pre-service teachers all had undergraduate science degrees. They discovered a variety of conceptions, many of which were inconsistent with the nature of science. This reinforces the notion that the teaching of the nature of science must be explicit and intentional (Lederman, 2007): students will not learn the nature of science simply by participating in science.

These outlined issues can contribute to the epistemologies that these teachers hold. These epistemologies are founded within these teachers' experiences of how they learned science: "teachers' personal epistemologies emerge from formal and informal learning experiences and serve as mental exemplars for constructing and evaluating their own teaching practices" (Jones & Carter, 2007, p. 1077). These epistemologies, or "sets of beliefs about knowing and learning" (p. 1077) act as a filter for future science teachers. The authors cited two studies (Stuart and Thurlow, 2000; Skamp, 2001) that demonstrated pre-service teachers' concepts of how to teach science are affected by their undergraduate science courses and science methods courses. However, "Skamp observed that [their views of an effective science teacher] changed once they began to teach in schools" (Jones & Carter, 2007, p. 1078) as their views of a good science teacher were formed mostly by their field experiences. Their views as learned in their undergraduate courses were supplanted by their field experiences. This is not to imply, however, that future teachers are unable to overcome their held epistemologies of how science should be taught. Professional development has been demonstrated to be an effective medium through which teaching beliefs and practices can be changed (Luft, 2001), although this is not always true (cf Cronin-Jones and Shaw, 1992).

Pre-service teachers' hold an inadequate view of the nature of science (Hanuscin & Akerson, 2006; Buaraphan, 2010). These inconsistent views coupled with environmental factors—limited curriculum resources, lack of funding, lack of proper equipment, colleagues who do not support them in their choice of methodology, little professional development, and so on—lead new teachers away from using inquiry in their classrooms (Anderson, 2007; Johnson, 2007; Fazio, Melville, & Bartley, 2010). This praxis results in a movement away from ideal teaching towards more traditional teaching (Peacock and Gates, 2000; Kelchtermans & Ballet, 2002).

These obstacles raise an issue of concern as the success of inquiry-based reform in science education rests largely on teachers (Bybee, 1993; Savasci-Acikalin, 2009) and teachers are key to successful curriculum change (Feldman, 2000; Fullan, 2007). Although research has identified how to help teachers overcome obstacles to using inquiry, science curricular and pedagogical reforms remain unsuccessful. The AAAS (1990) attributes a lack of teacher voice to the reforms' failure. Many of the reforms in science education are brought top-down from administrators, politicians, and science-based organizations like the NRC and the AAAS (Johnson, 2007). The AAAS (1990) stated:

> Moreover, reform cannot be imposed on teachers from the top down or the outside in. If teachers are not convinced of the merit of proposed changes, they are unlikely to implement them energetically. If they do not understand fully what is called for or have not been sufficiently well prepared to introduce new content and ways of teaching, reform measures will founder [sic]. In either case, the more teachers share in shaping reform measures and the more help they are given in implementing agreed-upon changes, the greater the probability that they will be able to make those improvements stick (p. 213).

The voice, values, and beliefs of teachers cannot be excluded from the reform process. Failure to do so inevitably results in the failure of the reform.

Ratcliffe (2012) echoed this noting, "education for scientific literacy cannot be divorced from a consideration of [teacher] ethics and values" (p. S35). An aspect of this includes the values and beliefs teachers bring with them in designing and implementing new curriculum (Jones & Carter, 2007). A review of research in this area showed that teachers' values and beliefs impact the design and implementation of science curriculum (Bryan, 2012). For example, Cronin-Jones (1991) observed two teachers who held that science is a body of knowledge for learning, not for student-directed learning through inquiry. Their teaching style focused on transmitting content knowledge to the students. Their teaching style was not aligned to the "discovery-oriented constructivist model of knowledge acquisition" (p. 238) that undergirded their curriculum. Thus, their beliefs of how science should be taught interfered with how the new curriculum should have been taught. On the other hand, Levitt (2001) interviewed sixteen science teachers regarding their beliefs and implementation of science curriculum. She found that although there were gaps between the teachers' beliefs and practice, "these teachers' beliefs about the teaching of science aligned with the general elements of the philosophy underlying current recommendations in science education reform" (p. 19). Levitt found that the teachers were moving towards teaching science through inquiry but at varying paces due to their individual beliefs:

> Teachers, as individuals, change at their own pace…. Like the students they teach, teachers have individual concerns and needs that must be addressed before they move forward toward adopting the principles of reform (p. 20).

Problem Statement

How teachers experience curriculum change is a subjective process in which teachers make their own meanings (Fullan, 2007). Keys and Bryan (2001) claimed, "because the efficacy of reform rest largely with teachers, their voices need to be included in the design and implementation of inquiry-based curriculum" (p. 631). Consequently, it is important to research how teachers experience change in order to successfully implement new curriculums (Park & Sung, 2013), as teachers will embed their beliefs and values into the curriculum (Brown, 2009).

There are numerous studies that describe how teachers experience curriculum change. Dias, Eick, and Brantley-Dias (2011) completed a study on how a science teacher educator returned to the science classroom to experience teaching an inquiry curriculum.

Coenders, Terlouw, and Dijkstra (2008) examined high school chemistry teachers' beliefs regarding their wants and needs in transitioning to a new curriculum. Dreon (2012) researched the experience of two beginning science teachers implementing inquiry. Each of these studies will be discussed more in depth in the literature review.

The literature on how beliefs influence science teachers' use or non-use of inquiry is inconsistent (Savasci-Acikalin, 2009). In addition, many of these studies are conducted as case studies and are not phenomenological. What distinguishes phenomenological research is uncovering the essence to an experience with the research participant(s). "These essences," Patton (1990) wrote, "are the core meanings mutually understood through a phenomenon commonly experienced" (p. 70). Essences are the "structure of essential meanings that explicates a phenomenon of interest" (Dahlberg, 2006, p. 11). Phenomenology offers detailed insight into how an individual experiences a given phenomenon, the meaning they make from that experience, and offers the reader a gateway into understanding the experience of the phenomenon (Patton, 2002). Phenomenology focuses on the individual's understanding of the experience. This understanding is influenced by their own background and thus varies from others who may have gone through the same experience.

This dissertation filled a gap within the phenomenological academic research on how science teachers experience the implementation of an inquiry curriculum. Additionally, there is limited research on how veteran teachers experience the implementation of inquiry curriculum. Thus, this dissertation sought a cohort of veteran science teachers who all transitioned from teaching a traditional, teacher-focused curriculum to an inquiry-based curriculum.

Research Questions

The purpose of this phenomenological study was to describe how science teachers experience the implementation of an inquiry-based curriculum. The questions being address in this study were:

1. How do science teachers experience the implementation of a new inquiry-based science curriculum?
    a. How do their beliefs of and values in science education contribute to their implementation of a new inquiry-based science curriculum?
2. What are the essences of their experiences?

References

Aguirre, J.M., Haggerty, S.M., & Linder, C.J. (1990). Student-teachers' conceptions of science teaching and learning: A case study in preservice science education. *International Journal of Science Education, 12*(4), 381-390.

Allum, N. (2011). What makes some people think astrology is scientific? *Science Communication, 33*(3), 341-366.

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

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy.* New York, NY: Oxford University Press.

Anderson, C.W. (2007). Perspectives on science learning. In S.K. Abell & N.G. Lederman (Eds.), *Handbook of research on science education* (pp. 3-30). Mahwah, NJ: Lawrence Earlbaum Associates.

Anderson, R.D. (1998). *The research on teaching as inquiry*. A commissioned paper prepared for the Center for Science, Mathematics and Engineering Education at the National Research Council.

Anderson, R.D. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education, 13*(1), 1-12.

Baker, D.W. (2006). The meaning and the measure of health literacy. *Journal of General Internal Medicine, 21*(8), 878-883.

Benson, L., Harkavy, I. R., & Puckett, J. L. (2007). *Dewey's dream: Universities and democracies in an age of education reform: civil society, public schools, and democratic citizenship*. Philadelphia: Temple University Press.

Bramble, J. (2005). Reshaping Their Views: Science as Liberal Arts. *New Directions for Teaching and Learning*, (103), 51-60.

Brown, M.W. (2009). The teacher-tool relationship: Theorizing the design and use of curriculum materials. In J.T. Remillard, B.A. Herbel-Eisenmann, and G.W. Lloyd (Eds.) *Mathematics teachers at work: Connecting curriculum materials and classroom instruction* (pp. 17-36). New York, NY: Routledge, Taylor-Francis.

Bryan, L. (2012). Research on science teacher beliefs. In B.J. Fraser, K. Tobin, & C.J. McRobbie (Eds.) *Second international handbook of science education*. (pp. 477-495). New York, NY: Springer.

Buaraphan, K. (2010). Pre-service and in-service science teachers' conceptions of the nature of science. *Science Educator, 19*(2), 35-47.

Buxton, C, & Provenzo, E.F. (2011). "Natural philosophy" as a foundation for science education in an age of high-stakes accountability. *School Science and Mathematics, 111*(2), 47-55.

Bybee, R. W. (1993). *Reforming science education: Social perspectives and personal reflections*. New York, NY: Teachers College Press.

Coenders, F., Terlouw, C., & Dijkstra, S. (2008). Assessing teachers' beliefs to facilitate the transition to a new chemistry curriculum: What do the teachers want? *Journal of Science Teacher Education, 19*(4), 317-335.

Cronin-Jones, L.L. (1991). Science teacher beliefs and their influence on curriculum implementation: Two case studies. *Journal of Research in Science Teaching, 28*(3), 235-250.

Cronin-Jones, L.L., & Shaw, L.E., Jr. (1992). The influence of methods instruction on the beliefs of prospective elementary and secondary science teachers: Preliminary comparative analysis. *School Science and Mathematics, 92*(1), 14-22.

Dahlberg, K. (2006). The essence of essences – the search for meaning structures in phenomenological analysis of lifeworld phenomena. *International Journal of Qualitative Studies on Health and Well-being, 1*(1), 11-19.

Darling-Hammond, L. (2010). *The flat world and education: How America's commitment to equity will determine our future.* New York, NY: Teachers College Press.

DeBoer, G. E. (1991). *A history of ideas in science education: Implications for practice*. New York: Teachers College Press.

Dewey, J. (1910). Science as subject-matter and as method. *Science, 31*, 121-127.

Dewey, J. (1916). Method in science teaching. *The Science Quarterly, 1*, 3-9.

Dewey, J. (1934). *A common faith*. New Haven, MA: Yale University Press.

Dias, M., Eick, C.J., & Brantley-Dias, L. (2011). Practicing what we teach: A self-study in implementing an inquiry-based curriculum in a middle grades classroom. *Journal of Science Teacher Education, 22*(1), 53-78.

Dreon, O. (2012). Being in the hot spot: A phenomenological study of two beginning teachers' experiences enacting inquiry science pedagogy. *Teachers and Teaching: Theory and Practice, 18*(3), 297-313.

Fazio, X., Melville, W., & Bartley, A. (2010). The problematic nature of the practicum: A key determinant of pre-service teachers' emerging inquiry-based science practices. *Journal of Science Teacher Education, 21*(6), 665-681.

Feldman, A. (2000). Decision making in the practical domain: A model of practical conceptual change. *Science Education, 84*(5), 606-23.

Fullan, M. (2007). *The new meaning of educational change* (4th ed.). New York, NY: Teachers College Press.

Hanuscin, D.L. & Akerson, V.L. (2006). Integrating nature of science instruction into a physical science content course for preservice elementary teachers: NOS views of teaching assistants. *Science Teacher Education, 90*(5), 912-935.

Hazen, R.M. & Trefil, J. (2009). *Science matters: Achieving scientific literacy.* New York, NY: Anchor Books

Hoh, Y.K. (2013). Pre-service versus in-service science teachers' views of NOS. *Teaching Science: The Journal of the Australian Science Teachers Association*, *59*(2), 31-36.

Hoff, D. J. (1999). The race to space rocketed NSF into classrooms. *Education Week, 18*(36), 34.

Johnson, C. (2007). Technical, political and cultural barriers to science education reform. *International Journal of Leadership in Education, 10*(2), 171-190.

Jones, M.G., & Carter, G. (2007). Science teacher attitudes and beliefs. In S. Abell & N. Lederman (Eds.), *Handbook of research on science education* (pp. 1067–1104). Mahwah, NJ: Lawrence Erlbaum Associates.

Kahle, J.B. (2007). Systemic reform: Research, vision, and politics. In Abell, S.K. & Lederman, N.G. (Eds.), *Handbook of research on science education* (pp. 319-343). Mahwah, NJ: Lawrence Erlbaum Associates.

Kelchtermans, G., & Ballet, K. (2002). The micropolitics of teacher induction: A narrative-biographical study on teacher socialization. *Teaching and Teacher Education*, *18*(1), 105–120.

Keys, C. W. & Bryan, L.A. (2001). Co-constructing inquiry-based science with teachers: essential research for lasting reform. *Journal of Research in Science Teaching, 38*(6), 631-645.

Lederman, N.G. (2007). Nature of science: Past, present, and future. In S.K. Abell & N.G. Lederman (Eds.), *Handbook of research on science education* (pp. 831-880). Mahwah, NJ: Lawrence Earlbaum Associates.

Lerner, L.S., Goodenough, U., Lynch, J., Schwartz, M., & Schwartz, R. (2012). *The state of state science standards*. Retrieved from: http://files.eric.ed.gov/fulltext/ED528964.pdf

Levitt, K. E. (2001). An analysis of elementary teachers' beliefs regarding the teaching and learning of science. *Science Education, 86*(1), 1-22.

Luft, J.A. (2001). Changing inquiry practices and beliefs: The impact of an inquiry-based professional development programmed on beginning and experience secondary teachers. *International Journal of Science Education, 23*(5), 517-534

Miller, J.D. (1998). The measurement of civic scientific literacy. *Public Understanding of Science, 7*(3), 203-223.

Mooney, C., & Kirshenbaum, S. (2009). *Unscientific America: How scientific illiteracy threatens our future*. New York: Basic Books.

National Research Council (2012). *A framework for K-12 science education: Practice, crosscutting concepts, and core ideas.* Washington, DC: National Academy Press.

National Research Council. (2000). *Inquiry and the National Science Education Standards: A guide for teaching and learning*. Washington DC: National Academy Press.

NGSS Lead States. (2013). *Next generation science standards: For states, by states*. Washington, D.C: National Academies Press.

Noddings, N. (2007). *When school reform goes wrong*. New York, NY: Teachers College Press.

Oreskes, N. & Conway, E.M. (2010). *Merchants of doubt: How a handful of scientists obscured the truth on issues from tobacco smoke to global warming.* New York, NY: Bloomsbury Press.

Park, M. & Sung, Y. (2013). Teachers' perceptions of recent curriculum reform and their implementation: What can we learn from the case of Korean elementary teachers? *Asia Pacific Journal of Education, 33*(1), 15-33.

Patton, M. Q. (1990). Qualitative Evaluation and Research Methods (2nd ed.). Newbury Park, CA: Sage.

Patton, M.Q. (2002). Qualitative research & evaluation methods (3rd ed.). Thousand Oaks, CA: Sage.

Peacock, A., & Gates, S. (2000). Newly qualified primary teachers' perceptions of the role of text material in teaching science. *Research in Science & Technology, 18*(2), 155-170.

Piaget, J. (1952). *The origins of intelligence in children*. New York, NY: International Universities Press.

Ratcliffe, M. (2012). Science literacy and scientific values: Implications for formal education. *RendicontiLincei*, *23*(1 Supplement), 35-38.

Roberts, D.A. (2007). Scientific literacy/science literacy. In S.K. Abell & N.G. Lederman (Eds.), *Handbook of research on science education* (pp. 729-780). Mahwah, NJ: Lawrence Earlbaum Associates

Savasci-Acikalin, F. (2009). Teacher beliefs and practice in science education. *Asia-Pacific forum on Science Learning and Teaching, 10*(1), 1-14.

Schiro, M.S. (2009). *Curriculum theory: Conflicting visions and enduring concerns.* Thousand Oaks, CA: Sage Publications, Inc.

Seethaler, S. (2009). *Lies, damned lies, and science: How to sort through the noise around global warming, the latest health claims, and other scientific controversies.* Upper Saddle River, NJ: FT Press.

Ültanir, E. (2012). Epistemological glance at the constructivist approach: Constructivist learning in Dewey, Piaget, and Montessori. *International Journal of Instruction, 5*(2), 195-212.

Willingale-Theune, J., Manaia, A., Gebhardt, P., De Lorenzi, R., & Haury, M. (2009). Introducing modern science into schools. *Science, 325*, 1077-1078.

Chapter 2:

Review of Literature

Inquiry curricula have been developed to address the issue of scientific illiteracy. Traditional, teacher-centered curricula do not provide students with the necessary tools and understandings to become scientifically literate. Yet these curricula remain dominant in science classrooms. Consequently, researchers have asked what can be done to increase science teachers' use of inquiry curricula. Answering this question has produced a plethora of research that examines teachers' perceptions, struggles, and implementation of inquiry curricula.

Researchers have also sought solutions to increase teacher use of inquiry. These solutions—most commonly professional development and the use of inquiry kits—make it easier for teachers to see the benefits of inquiry and implement inquiry in their classroom. Undergirding these solutions are the beliefs science teachers have regarding science education and inquiry. These solutions are also upheld by systemic supports. A lack of such supports undermines the effectiveness of the solutions and the teachers' ability to implement inquiry in their classrooms.

This chapter will first explore how inquiry is defined in the academic research and compare it to how teachers implement inquiry in their classrooms. This will show that there is a mismatch between how inquiry is defined in the research and what teachers do in their classroom. This establishes the need for solutions for implementing inquiry as it is envisioned. I will provide an overview of what is needed for teachers to successfully implement inquiry in their classrooms: an examination of their beliefs, the use of curricular kits, and effective professional development. I will conclude by identifying the lack of a phenomenological perspective in inquiry research and how this dissertation served to fill that gap.

Defining Science Inquiry

There is no clear definition of inquiry in the context of science education (Appleton, 2007; R. Anderson, 2002; C. Anderson, 2007). Anderson (2007) posited that there are three versions of inquiry and they "are fairly distinct from each other, even though they also have many connections" (p. 808). Scientific inquiry is his first version of inquiry. It describes, "the work of scientists, the nature of their investigations, and the abilities and understandings required to do this work" (p. 808). This version of inquiry is situated closely to the nature of science: "the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development" (Lederman, 2007, p. 833). The second version of inquiry is inquiry learning. This "refers to an *active* process of learning" (Anderson, 2007, p. 808) that students do, rather than have done to them. Inquiry learning engages students in many stages of activity and communication. Inquiry learning is closely connected to constructivism as both pose learning as an active process, depend on the prior knowledge and conceptions of the individual, formed understandings are dependent on context, and both are a social process (p. 809). The third version of inquiry is inquiry teaching. Inquiry teaching is closely connected with inquiry learning. However, inquiry teaching is conducted through multiple forms and "the process of inquiry teaching is not as well understood" (p. 810) compared to inquiry learning.

There is consensus that the National Research Council's (2000) definition of inquiry is most useful because of its familiarity and its emphasis on the varied approaches to inquiry (Asay & Orgill, 2009). The National Research Council's (2000) definition of inquiry poses five identifying features:

- The learner engages in scientifically oriented questions,
- The learner gives priority to evidence in responding to the question,
- The learner formulates explanations from evidence,
- The learner connects explanations to scientific knowledge, and
- The learner communicates and justifies explanations.

Variations exist within these features. For example, in less teacher-directed inquiry a student poses his or her own scientific question for investigation. In contrast, in more teacher-directed inquiry a teacher may give a student a question to investigate and provide the student with the materials and resources to do so.

These identifying features were built upon the American Association for the Advancement of Science's [AAAS] *Benchmarks for Scientific Literacy* (1993) and *Science for all Americans* (1991). In *Science for all Americans* (1991), AAAS noted "inquiry is not easily described apart from the context of particular investigations" (p. 4) Therefore, inquiry is not simply a step-by-step method through which students can learn about science. Rather, inquiry has "certain features of science that give it a distinctive character as a mode of inquiry" (p. 4). These characteristics include demanding evidence for claims, blending logic and imagination, explaining and predicting, identifying and avoiding bias, and lacking authoritarianism.

Undergirding these characteristic modes of inquiry is the AAAS' (1993) release of its benchmarks for science learning. The benchmarks were released, in part, to help educators implement inquiry in the science classroom. The benchmarks were also released to reduce the amount of information covered in science courses, situate students within a society that requires an increased literacy in science, math, engineering, and technology, and focusing on skills of critical and logical thinking over those of factual memorization. These ideas become clear when one reads through some of the sample benchmarks:

- "By the end of the 8th grade, students should know that like other animals, human beings have body systems for obtaining and deriving energy from food and for defense, reproduction, and the coordination of body functions" (p. 129)
- "By the end of the 5th grade, students should know that planets change their positions against the background of stars" (p. 63)
- "By the end of the 12th grade, students should know that chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways" (p. 121)

Each of these benchmarks has the potential for being implemented through inquiry. For example, with the second sample benchmark, students could design a method for collecting and reporting data that would allow them to track the movement of the planets in relation to the stars.

Although the benchmarks allow for inquiry, the phrasing of the benchmarks still promotes memorization "students should know that." The recent release of the Next Generation Science Standards [NGSS] builds upon these by creating performance expectations of science and engineering practices, disciplinary core ideas, and crosscutting concepts (NGSS Lead States, 2013). For example, when learning about earth's systems, a high school student is expected to "plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes" or "develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere" (p. 282). This is in stark contrast to previous standards that may only have students follow a pre-written lab on water or state facts about the carbon cycle. In a review all state science standards from 2012, many standards were found to be too vague, have no measure of understanding, lacking interconnectedness between ideas and practices, and lacking scientific inquiry (Lerner, Goodenough, Lynch, Schwartz, & Schwartz, 2012).

The new standards are developed upon the release of the National Research Council's (2012) report on K-12 science education. Although the report is limited in its explicit discussion of inquiry, many features, characteristics, and modes of inquiry are present. The NRC stated, "all sciences share certain common features at the core of their inquiry-based and problem-solving approaches" (p. 26) which include supporting claims with evidence, argumentation and analysis, and engaging in science as a social enterprise. These features are known as scientific practices, which Crawford (2014) described as an attempt to rebrand the term inquiry. Osborne (2014) supported this rebranding as confusion exists with the term inquiry and what it means to teach through inquiry. He argued that science should be taught from a perspective of scientific practices. There is less ambiguity around the phrase scientific practices as NGSS clearly defined each of the eight scientific practices. He argued the NGSS scientific practices offer "greater clarity of goals about what students should experience, what students should learn, and an enhanced professional language for communicating meaning" (p. 179).

The confusion around the term inquiry has been documented in several studies. Ireland, Watters, Brownlee, and Lupton's (2014) study on how 20 science teachers describe inquiry resulted in over six definitions grouped into three categories (this study is discussed in more detail in the following section). In addition, teachers may be confused as to what science inquiry is as each academic discipline (scientific or otherwise) has its own definition of inquiry (Capps, Crawford, & Constas, 2012). This can be detrimental, as teachers who believe they are implementing inquiry may not be doing so (NRC, 1996; Martin-Hansen, 2002). However, this ambiguity is beneficial as it allows educators to respond to the needs of their students. Keys and Bryan (2001) found that inquiry cannot be one mode of teaching or learning because "teaching actions will necessarily differ based on facts in the local environment, such as teacher knowledge, student age, student language proficiency, etc." (p. 632). Thus, the classroom and student characteristics will influence how inquiry is implemented in the classroom.

Teachers and Inquiry

Although there is consensus on the characteristics of inquiry, educators have a mismatch between the established ideas of inquiry and what they do in their classrooms. Martin-Hansen (2002) noted that some science educators believe they are doing inquiry when they are not. They confuse inquiry with hands-on activities that are simply a "cookbook lesson in which students follow teacher directions to come up with a specific end point or product" (p. 37). The NRC (1996) identifies the often perceived equivalence between hands-on and inquiry as one of the five myths of inquiry learning. The others included all science needing to be taught through inquiry, inquiry only happens when students generate their own questions, and that inquiry can be taught regardless of subject matter.

This confusion around inquiry is further exacerbated within works like the NRC's (1996) *National Science Education Standards* or AAAS' (1993) *Benchmarks for Science Learning* which both advocate for multiple methods of inquiry learning science. The NRC (1996) wrote that inquiry "does not imply that all teachers should pursue a single approach to learning science" (p. 2). However, the recent NRC (2013) framework on teaching and learning science is clearer in what inquiry embodies: "respect for the importance of logical thinking, precision, open-mindedness, objectivity, skepticism, and a requirement for transparent research procedures and honest reporting of findings" (p. 248). It is too soon to determine what affect this document will have on teachers' understanding and implementation of inquiry in their classrooms.

Ozel and Luft (2013) used the NRC's (2000) features of inquiry rubric to assess how beginning science teachers conceptualize and use inquiry and how that changes as they teach. They found first-year teachers had limited use of the features of scientific inquiry, primarily using scientific questions and priority to evidence in their lessons. While this showed limited use of the features of inquiry, Ozel and Luft found "agreement in the teachers' use of the essential features of inquiry and their reporting of the features in the classroom" (p. 314). This is in contrast to studies that have reported what science teachers say and do are often not consistent (Simmons et al., 1999). They further learned that the teachers' conceptions and use of inquiry did not change over the time they observed the teachers, even though the teachers had access to supporting mentors and inquiry curriculum materials. However, other studies (e.g. Flick, 2006) found that science teachers tend to expand their views of inquiry over time.

Experienced science teachers, however, are able to identify features of inquiry more so than new science teachers. Kang, Orgill, and Crippen (2008) employed a survey to measure experienced science teachers' conceptions of inquiry. They provided study participants with teaching scenarios and asked them to identify those that were consistent with inquiry teaching. The participating teachers most often used three of the five NRC (2000) characteristic features of inquiry to identify inquiry teaching: engaging in scientifically oriented questions, giving priority to evidence, and formulating explanations based on evidence. Since many of the educators did not use the features of evaluating explanations in connection with scientific knowledge and communicating explanations, Kang, Orgill, and Crippen (2008) called for professional development that would, "help teachers see inquiry as a vehicle for teaching science content, instead of as a pedagogy that is separable from science content" (p. 352). They also saw that these experienced teachers had developed their conceptions of inquiry beyond their earlier, more limited conceptions.

Expanding upon this, Ireland et al. (2014) conducted a phenomenographical study to determine the different ways teachers conceptualize teaching science through inquiry. Analysis of interviews from 20 science teachers resulted in three categories of how inquiry was taught: experience, problem, and questions. Each of these categories represented differing teaching strategies, teaching goals, and inquiry foci. In the experience-centered approach, "there is an expectation that students must see, hear, feel and do interesting things to help them engage in science and learn science content well" (p. 1739). Within problem-driven inquiry, teachers gave students a problem to solve that "allowed students to engage with the topic at hand and have some ownership over the content outcomes through resolving the problem with the teacher's help" (p. 1741). Finally, in the questions category, “teachers structured their teaching around helping students to ask and answering their own (student) questions” (p. 1743). The approaches these teachers used were employed to fulfill “different outcomes in terms of the broader science curriculum” (p. 1746). Although the teachers implemented inquiry in a way that fit their views of the curriculum, Ireland et al. explained, “many teachers were describing a practice inconsistent with established ideas in science education” (p. 1746). Such inconsistencies included using personal experience and expert opinion in creating explanation rather than relying on data, problem solving through playtime rather than through rigorous experimentation, and having students experience the nature of science rather than understand and employ it.

Breslyn and McGinnis (2011) identified many studies conducted on teachers and inquiry that did not take into consideration the teachers’ discipline, or specific science content taught (e.g. physics, chemistry, or biology). They conducted a mixed-methods study of sixty secondary National Board Certified Science Teachers across the United States within the disciplines of biology, chemistry, earth science, and physics. Based on the work of Greene (2001) their study sought to find how the teachers’ discipline influenced their use of and beliefs about inquiry-based teaching and learning. Further, they explored how teaching more than one discipline would influence the teachers’ use of and beliefs about inquiry-based teaching and learning. Their analysis found variation between the disciplines in how inquiry was implemented. For example, they discovered physics teachers are more likely to enact inquiry as modeling—having students generate mathematical equations for observed phenomena—whereas earth science teachers approach inquiry as students conducting scientific investigations. They suggested that a teacher’s discipline “appears to be the driving fact in teacher's conception and enactment of inquiry" and "teachers' conceptions of inquiry are flexible and often adapt to disciplinary contexts" (p. 73).

These various studies echo Anderson's (2002) summarization of research on teachers and their implementation of inquiry. "Research indicates that inquiry teaching is possible for many teachers to initiate, although the research is not clear on just how difficult it is do to [sic] so, what percentage of teachers are able to be successful at it, or how many are likely to choose to teach in this manner" (pp. 6-7). He discussed various dilemmas teachers have in implementing inquiry in the classroom noting, "much of the difficulty is internal to the teacher, including beliefs and values to the students, teaching, and the purpose of education" (p. 7).

Thus, it becomes evident that teachers' conceptions of teaching science as inquiry, and the values and beliefs they hold therein, cannot be divorced from classroom practice. A focus on teachers is necessary when implementing inquiry curriculum reform (Hawley and Valli, 1999; Kali, Linn, and Roseman, 2008). Although science teachers are seen as key to the successful implementation of inquiry reform (Bybee, 1993), teachers cannot tackle this endeavor alone. Implementing inquiry requires teachers, well-designed curricula, and a systemic support.

Implementing Inquiry Successfully

Numerous science education reforms have been introduced to US public schools (Kahle, 2007). Powell and Anderson (2002) define science education reform as changing how science is taught and what is taught in science. These reform efforts include *Science-The Endless Frontier* (Bush, 1945), *Man: A Course of Study* (Education Development Center, Dow & Bruner, 1968), *A Nation at Risk* (National Commission on Excellence in Education, 1983), and *No Child Left Behind Act* (2003). Yet, each of these reforms, and many others, has not resulted in a population of students that are scientifically literate. This is not to say that the reforms are without success; many of the reforms resulted in foundational resources for future reforms, such as *Science for All Americans* (AAAS, 1990) and the *National Science Education Standards* (NRC, 1996). Further, researchers have identified issues with these reforms, including outdated texts and a lack of focus on the role, beliefs, and attitudes of teachers (Kahle, 2007).

Implementing inquiry curricula requires the effort of the individual teacher and various, interacting systemic aspects: appropriate materials, a teacher focus, and systemic support (Anderson, 2007). Appropriate materials include those that are standards-based, situated within a framework of inquiry, and are shown to be effective through field testing (Powell & Anderson, 2002). A teacher focus includes an examination of teachers' beliefs and attitudes towards teaching with inquiry. Systemic support can be provided in a number of ways: professional development and growth, having a vision for education, and contextualizing to account for the setting and individuals affected. Professional development, argued Sykes (1999), is the centerpiece for fostering change in teachers.

Inquiry Curriculum Materials

Curricular materials are important to the successful implementation of inquiry as these materials provide the foundation for quality inquiry education (Anderson, 2007). Several kits are in the market today to assist science teachers in implementing inquiry learning. These commercially available kits provide a packaged research-based curriculum grounded in best practices for science education. The investigations and activities are inquiry-based. The investigations often guide students through a process through which they learn content and experience the nature of science. These kits contain textbooks (i.e. lab manuals or activity guides for students as compared to traditional textbooks), teacher resources (e.g. background information, scripts, answer keys, grading rubrics, assessments, misconception guides, etc.), and lab materials needed for each investigation.

The Science and Technology Concepts [STC] Program, created by the Smithsonian Institution (2015) and published by Carolina Biological, is one example of these kits. These kits, available for grades K-10 and aligned with the national science education standards, use a four-stage learning approach: focus, explore, reflect, and apply. These kits come pre-packaged with most of the materials teachers and students need to implement the lesson. The textbooks are activity guides that contain procedures for completing investigations. Following the procedures are readings (e.g. interviews with scientists or extension information about the topic) that allow students to further learn about their investigation. Some lessons require that students design their own investigation including the procedures, variables, what data to collect and how to record and report it. The accompanying teacher's edition includes background information, recommendations on how to help students with their investigations, suggestions for using science notebooks, and resources for helping students to write scientifically. These kits are currently undergoing NGSS alignment. As of October 2015, only one kit, *Electricity, Waves, and Information Transfer* (Smithsonian Institution, 2015), is now fully aligned with NGSS.

Science Education for Public Understanding Program [SEPUP] is another commonly used curricular kit. These kits are issue oriented and allow students to "gain understanding of scientific principles, concepts, and definitions by performing hands-on laboratory activities that culminate in real-life situations that must be resolved using the evidence students gathered" (Ogens & Koker, 1995, p. 344). SEPUP connects well with the science-technology-society [STS] theme of learning science. Mansour (2009) offered STS is "an interdisciplinary field of study that seeks to explore and understand the many ways that modern science and technology shape modern culture, values, and institutions, on one hand, and how modern values shape science and technology, on the other" (p. 287). Or, as Yager (1996) put it: having students work within their own environment to address their own issues. STS connects well with inquiry as it is rooted within a Deweyan democratic ideal of society: to address and solve issues that affect human life (Cheek, 1992). Solving such issues requires an inquiry framework. Further, STS is believed to address the concern of scientific illiteracy (Dimopoulos & Koulaidis, 2003). Examples of issues addressed by SEPUP include how diseases spread in populations and how to respond to environmental disasters (e.g. oil spills). The kits contain the materials needed for the lessons, have student activity guidebooks, and a comprehensive teacher's manual that contains background, pacing, scripting for the teacher, and grading rubrics.

Questions can be raised about the effectiveness of these kits. How do students' understanding of the nature of science and science concepts differ between those who use the kit and those who do not? How does the use of kits effect information retention? How do science teachers implement these kits? How are their beliefs and values in teaching science manifested when using a kit? Although the available literature on science kits is limited, there are studies available that begin to address these questions.

Houston, Fraser and Ledbetter (2008) learned that students who had exclusively learned through a science kit had significantly improved their understanding of the concept addressed as measured by a pretest and posttest compared to students who used only a textbook or a combination of a textbook and kit. They concluded:

> Both qualitative and quantitative data supported the effectiveness of science kits in terms of student attitudes and satisfaction. This is important because student attention and participation in the class are necessary for learning to occur. In classes with a lack of attention or participation, students were not able to accurately explain the science concepts they had been taught. It was also observed that students who had been more actively involved in the lesson were better at remembering what was learned (p. 40).

Similarly, Dickerson, Clark, Dawkins, and Horne (2006) conducted a study to examine the efficacy of science kits. The kits included STC, Full Option Science System [FOSS], Teaching Relevant Activities for Concepts and Skills [TRACS], National Energy Education Development [NEED], and a locally designed kit for the school. The sample size included 2,299 students in grades 3-5 from ten schools. They used validated researcher-designed tests, "to assess student conceptual understanding constructed from experiential learning" (p. 46). They discovered, "systemic implementation of science kits is successful in some contexts at enhancing student understanding as measured by application-based content questions" (p. 48). The examined contextual factors, "including end-of-grade (EOG) scores on state standardized tests, percentage of free/reduced lunch, percentage of non-white student population of school, and school scheduling format (i.e., tradition vs. year-round enrollment)," (p. 45) were used only to select schools for the study and to pair similar treatment and control groups. The authors did not elaborate on how these contexts may have affected the outcome of their study. While they made their treatment and control pairs as similar as possible, they discussed, "many variables exist such as frequency of kit use, implementation of kits, alternative approaches implemented in comparison schools, and teacher and student affective variables," (p. 48) may have contributed to their findings.

Young and Lee (2005) examined the use of kits on students' understanding of content within the context of teacher professional development. They compared students who used a kit taught by teachers who had intensive professional development to students who did not use a kit and whose teachers lacked systemic science professional development. They concluded, "the results of this study add to the evidence that sustained education programs that combine high-quality materials and intensive teacher processional development in science and reform pedagogy have a positive impact on children's learning of science" (p. 480). They further found that teachers who did not teach using a science kit covered more topics in the year in a shorter duration, their students did not perform as well as students who used the kits, and the teachers not using these kits felt less prepared to teach through constructivist pedagogies.

Jones and Eick (2006) took a different approach in researching the use of kits and science educators. They sought to find how two teachers piloted various STC kits within their classrooms within a context of the teachers' pedagogical and curricular interests. Both teachers implemented the same kits. They discovered that the teachers implemented the kits in different ways. One teacher became more student-centered whereas the other remained more teacher-centered. Their pedagogical strategies also differed:

> Mr. Baldwin became interested in journaling and assessment, whereas Ms. Rodman explored cooperative-learning strategies. This evolution led to different exploration into pedagogical content knowledge in which the teachers, due to their own interests, were exploring the system interaction of content and pedagogy (p. 507).

It was clear from their findings that the beliefs of the teachers influenced how they experienced the kit. Although they had some common experiences (e.g. frustration when initially using the kit and excitement at having a fully stocked kit to use), how they implemented the kit and how they taught with the kit was different. Yet, how they taught with the kit was different than how they had previously taught. One teacher previously had very structured lessons and relied extensively on a traditional textbook as the scope and sequence of her curriculum. The use of the kit changed her to more cooperative student learning, using inquiry-based lessons, and relying less on the textbook as a source of information and as a guide for curriculum structure. The other teacher previously had taught through open inquiry: a learning style in which students create the questions and design their own investigations to answer these questions. After using the kit, this teacher employed guided inquiry, adjusted his assessment style to include reflective journals and to include a performance component. The authors concluded, “implementing an excellent, inquiry-based curriculum that includes pedagogical information and content knowledge can create changes in teachers’ pedagogical content knowledge and practical knowledge through practice that supports inquiry” (p. 510).

Several years later, Eick participated in a self-study of implementing a science curriculum kit (Dias, Eick, and Brantley-Dias, 2011). The goal was to test his “conceptual knowledge of inquiry-based practice against the practical knowledge that could be learned through the daily work of teaching adolescents using a reform-based curriculum" (p. 54). He took a sabbatical from his work as a professor of science education to become an eighth and ninth grade teacher again. In the semester he taught, he used the Interactions in Physical Science guided inquiry curriculum. This curriculum uses a conceptual change model with a community of scientists approach. After analyzing data from interviews and observations, the researchers came to four interwoven assertions about Eick's experience.

The assertions focused on how the curriculum he was given was very scripted and formulaic. As a result, the curriculum did not engage the students throughout the entire semester. Further, the curriculum did not allow the students to maintain excitement, find personal relevance, or engage in their creativity. The curriculum focused too heavily on data collection and analysis. It neglected other aspects of the nature of science, namely the creative endeavor. In addition, Eick gained a renewed understanding of the physical and emotional energy needed to teach inquiry in the middle school. His recommendation is for new teachers to go slow, but go. Together, the researchers provided that "teachers must seek creative and varied ways for their students to learn science via relevant experiences that connect to student interests, utilizing more open forms of inquiry where appropriate" (p. 74). They go on to explain that the kits should be guides or general frameworks for inquiry. The kits should be situated within the students' needs and interests.

In an older study, Cronin-Jones (1991) observed how teachers' beliefs impacted the use of an inquiry science kit in their classrooms. She found, "teacher beliefs about the ability levels of students in a given age group and beliefs about which student outcomes are most important also exert powerful, and potentially negative, influences on the curriculum implementation process" (p. 247). She highlighted one of the teachers she observed skipping lessons in the kit because, "she did not feel that they were appropriate or worthwhile for her students" (p. 246). This is in contrast to another teacher who implemented all lessons in the kit but chose to primarily focus on the content of the lessons, rather than on the interaction and exploration the kits were designed to provide.

Teacher Focus

Another component of successful inquiry implementation is focusing on the teacher. A teacher focus examines the beliefs the teachers hold in regards to education. This area is important as the teacher's beliefs affect how they implement science curriculum (Remillard, 2005).

Research on teacher beliefs spans several decades. Within that time, many definitions for the term belief have been presented. Pajares (1992) summarized the diversity of how beliefs are defined within the academic literature:

> [beliefs] travel in disguise and often under alias—attitudes, values, judgments, axioms, opinions, ideology, perceptions, conceptions, conceptual systems, preconceptions, dispositions, implicit theories, explicit theories, personal theories, internal mental processes, action strategies, rules of practice, practical principles, perspectives, repertories of understanding, and social strategy… (p. 309).

One issue with defining the term belief is differentiating it from the term knowledge. In a literature review on teacher attitudes and beliefs, Jones and Cronin (2007) found variation in the definition of beliefs and found similar variation in contrasting beliefs from knowledge. Loucks-Horsley, Stiles, Mundry, Love, and Hewson (2010) more concretely stated *knowledge* are "those things that are supported by solid facts and research," while *beliefs* are "those things we are coming to know or believe based on personal experiences, observations, and convictions" (p. 22). Jones and Leagon (2014) offer that knowledge and beliefs are confusingly interrelated and exclusive as some (Nisbett & Ross, 1980) reported belief is a particular type of knowledge whereas others (Rokeach, 1968) believed knowledge is a component of a belief.

Savasci-Acikalin (2009) noted that much research on teacher beliefs is focused on the relationship between classroom practice and teachers' beliefs. She discussed that while this literature is diverse, covering topics from constructivism, goals of science education, inquiry, and thematic units, the "relationship between teacher beliefs and practice is controversial" (p. 2). She highlighted various studies that claim teacher beliefs are consistent with their classroom practice as well as those that claim teacher beliefs are inconsistent with their classroom practice.

Anderson (2007) stressed the importance of science teacher beliefs and adopting inquiry in their classrooms. He discussed that many of the hurdles teachers face in implementing inquiry are "grounding in [their] beliefs about science, students, and teaching, and in values concerning what is important" (p. 817). Lotter, Harwood, and Bonner (2007) reported that how teachers implement inquiry is based on the teachers' conceptions of inquiry, namely their conceptions of science, the purpose of education, students, and effective teaching. Additionally, Forbes and Davis (2010) noted, "teachers' beliefs play an important role in how and why they engage in certain types of science teaching practices, including inquiry" (p. 368). Crawford (2007) offered that teachers have conflicting beliefs (i.e. about teaching versus school culture) that affect how they teach.

This is further supported by a review of the research done by Keys and Bryan (2001). They wrote, “when reform efforts are based on documents that represent the intended curricula of researchers rather than the enacted curricula of teachers, there is a mismatch that impedes science education reform” (p. 635). They cited a study (Tobin & McRobbie, 1996) to demonstrate how powerful teacher beliefs are on enacting inquiry in the classroom. They summarized, “a secondary chemistry teacher in their study viewed himself simultaneously as a powerful keeper and transmitter of chemistry knowledge, and as a relatively powerless individual in terms of transforming the chemistry curriculum” (Keys & Bryan, 2001, p. 636).

Another study focused specifically on beginning elementary teachers’ beliefs on the use of driving questions in inquiry and how their beliefs changed over time (Forbes & Davis, 2010). For three years, the authors interviewed and reviewed reflective journal and logs of four recent graduates from an undergraduate elementary teacher program. Their analysis found that the teachers’ beliefs of and use in anchoring questions changed over the three-year period. For example, one of their teachers wanted to use anchoring questions to go beyond “description and recall and to promote student sense-making about scientific phenomena” (p. 377). She did not want science to be merely about the content and sought to make it meaningful to her students’ lives. In her second and third year, her beliefs of anchor questions shifted slightly. She found that she needed to include driving questions that would help the students answer the larger anchor question. The anchor question still applied to the students’ lives, but the students needed specific questions that would aid them in answering the broader anchor question.

Another teacher's beliefs in and use of anchoring questions was not reflected within the curriculum. She had to adapt the curriculum to fit her beliefs. She found that her time was limited and struggled to do so. As she continued teaching, however, her beliefs of using anchoring questions and her use of inquiry changed. In previous years, she avoided the use of questioning that would lead to inquiry learning. But, by her third year she, "expressed a desire to use questions to help students make connections across individual learning experiences and, later, to scaffold them in taking more responsibility for their own learning" (p. 382). She saw questions as a medium through which her students could learn through an inquiry model, thus giving the students more responsibility over their learning.

In contrast another teacher "expressed beliefs about the importance of anchoring questions in science to promote student sense-making and established a sense of purpose" (p. 377). Yet, this teacher struggled with this ideal in her second and third years because her students would seek to answer the question quickly, which limited their investigations. Ultimately, she wanted to find a way to use the questions "in ways that were motivating and engaging for her students" (p. 377).

Although I have already highlighted the following study in the first chapter, I find it is important to readdress it within the context of my literature review. Levitt's (2001) study of sixteen new science teachers examined their beliefs and how those shaped their implementation of inquiry curriculum. Similar to the findings of Ozel and Luft (2013), Levitt (2001) found that although new science teachers are limited in their use of inquiry, they still demonstrate aspects of it in their teaching. However, Levitt additionally found that this was connected to their beliefs about how science should be taught. Consistent with Kang et al. (2008), the beliefs in and practice of inquiry changed as the teachers had more experience with inquiry in the classroom. Further, Levitt (2001) concluded, "at least some of the beliefs expressed by the teachers came about as a result of implementing a program of science education reform" (p. 19).

Pajares' (1992) generalized that teachers' beliefs tend to remain consistent and difficult to change. It is possible, as seen in the aforementioned studies, for teachers' beliefs to change. Sustaining a change in teachers' beliefs can be difficult: the sociocultural context of the teacher may undo the belief change. That is, if teachers are not in an environment that is supportive of inquiry, they are likely to return to their previous teacher-centered beliefs (Stofflett, 1994). Starting that change, though, rests with effective professional development.

Professional Development

Teachers need effective professional development to help them implement the goals of science education reform. Effective professional development is "grounded solidly in research knowledge and on the particular needs, contexts, and circumstances of the participants" (Loucks-Horsley et al., 2010, p. 52). Hawley and Valli (1999) reached a similar definition of effective professional development based on a review of literature. They found much professional development is poorly designed, lacks teacher input, and is not a focus toward school improvement.

Effective professional development is not merely additive but transformative. Such professional development leads to meaningful change in science teachers. Transformative professional development has five key characteristics (Thompson & Zeuli, 1999, pp. 335-357):

1. A high level of cognitive dissonance to disrupt the teacher's current beliefs and practice.
2. Time, context, and support for teachers to think to resolve the dissonance.
3. Ensure the dissonance-creating and dissonance-resolving activities are connected to the teacher's students and contexts.
4. Provide a way for teachers to develop a repertoire for practice that is consistent with the new understanding that teachers are building.
5. Provide continuing support and engagement of new practices.

Consequently, this alters the deeply held beliefs of teachers such that they will be aligned with the tenets of reform efforts.

Loucks-Horsely et al. (2010) noted that professional development has had a history of adding new skills and content rather than helping educators address their held beliefs. The consequence of additive professional development is "inadvertently making choices that detract from student learning" (p. 70). Further, they noted how many teachers experience professional development advocating and demonstrating constructivism teaching methods, but how they are taught that is through traditional teaching (i.e. lecture). This type of professional development does not result in a change in teacher practice. As Loucks-Horsely et al. (2010, p. 87) articulated, "knowing what teachers know and what they want to learn also enables professional developers to build on teachers' prior knowledge respectfully, uncover common naïve ideas, and adjust the program as specific concerns arise."

This "knowing what teachers know" is captured by the teacher's pedagogical content knowledge (PCK). The origin of PCK is from Shulman (1986) who posited that PCK is a combination of a teacher's knowledge of their subject matter and the way through which it is taught. In a review of research on science teacher knowledge, van Driel, Berry, and Meirink (2014) highlighted the various ways PCK has since been addressed over the subsequent years. For example, Van Dijk and Kattman (2007) proposed that PCK consists of pedagogical knowledge, subject matter knowledge, and knowledge of context. Some (Cochran, DeReuiter, and King, 1993) see this as a synthesis of all knowledge needed for teaching, while others (Mason, 1999) see it as the ability to combine content knowledge with the ability to teach. Abell's (2007) review on science teacher PCK research culminated with a signification conclusion: science teachers have insubstantial knowledge of how their students learn science. This finding is significant as inquiry is student focused; if teachers lack knowledge of how their students learn, it would follow that they would struggle to teach through inquiry.

A second component of change must be systemic. That is, change must happen with educators, administrators, and the district (Sparks, 2002). A component of this is the goal setting that occurs with teachers, stake-holders, and district leaders as a way to ensure change occurs within a district (Waters and Marzano, 2006). Additional support exists between teachers. Wilson and Berne (1999) noted in a review of professional development that collaboration between teachers within and between schools resulted in the use of new teaching practices. These new practices were not specific to science, but teaching in general.

A third component of change is that it must be progressive and ongoing; it cannot happen in isolation and may take several years (Loucks-Horsely et al., 2010; Luft and Hewson, 2014). Supovitz and Turner (2000) argued that teachers engaged in fewer than 80 hours of professional development would not enact instructional practice change. They showed that teachers who had 80 or more hours of professional development reported more frequent use of inquiry practices in their classrooms. Teachers with fewer than 80 hours relied on more traditional-oriented instructional practices.

An example of effective professional development was observed in the early 1990s in Ohio (Supovitz, Mayer, & Kahle, 2000). Ohio implemented a statewide, inquiry-based professional development program called Discovery that focused on mathematics, physical, and life sciences. This program consisted of an intensive 6-week summer session totaling 160 contact hours and was open to teachers of all grade levels. During the subsequent school year, teachers were allowed release time for 6 days for additional follow-up sessions. Supovitz, Mayer, and Kahle (2000) were interested in “whether teacher attitudes toward inquiry-based instruction, preparation to implement inquiry-based instruction, and classroom use of inquiry-based teacher practices changed over time” (p. 337) as a result of this intense professional development. In short, the researchers found these teachers’ use of, attitudes of, and preparation for inquiry-based science instructions increased and was sustained over the examined three-year period. This result was found regardless of teachers’ individual or school characteristics.

In contrast, Johnson (2006) examined what barriers science teachers encounter while implementing National Science Education Standards based instruction while being enrolled in the same professional development as the teachers in the study done by Supovitz, Mayer, and Kahle (2000), albeit Johnson’s (2006) participants were in the Discovery program in 2000-2003. The program still offered a 2-week intensive course, 160 hours of professional development, and a vast network of professional support. She found there were technical, political, and cultural barriers that affected how the teachers implemented inquiry and instruction based on the National Science Education Standards. While the professional development was designed to provide change in instructional practice, many of the teachers in the study were unable to overcome the political and cultural barriers. Such political barriers included a lack of support from administration and lack of collaboration time. Cultural barriers included a mismatch between state assessments and how science should be taught through the National Science Education Standards, teachers having a limited understanding of standards-based instruction, and a focus on teaching to the test.

Johnson's (2006) recommendations of how to overcome these barriers are consistent with what Loucks-Horsely et al. (2010) describe as the on-going professional development needed for change to occur. Johnson (2006) recommended teachers have mentors who are experienced with teaching inquiry, have adequate time to engage with inquiry pedagogy and lessons, have time to reflect on their work, and have systemic (i.e. district-wide) support.

Professional learning communities (PLCs) offer a different approach to professional development for teachers. Stoll, Bolam, McMahon, Wallace, and Thomas (2006, p. 229) have defined PLCs as "a group of people sharing and critically interrogating their practice in an ongoing, reflective, collaborative, inclusive, learning-oriented, growth-promoting way." PLCs offer a de-centralized, teacher-initiated approach to professional development. The effectiveness of PLCs depends on several factors such as teachers' orientation to change, group dynamics, location, and school context.

Jones, Gardner, Robertson, and Robert (2013) examined one district's elementary teachers' experiences in science-focused PLCs. Surveys given to the teachers revealed varied results on the outcome reached within the PLCs, how effective the teachers felt the PLCs were, and the value the teacher placed on the PLCs. Since PLCs are decentralized, each PLC is unique. Although the district offered a model for the PLC, there was variation in the purposes of the PLCs. Some administrators used the PLCs as time to deliver announcements to teachers rather than allow teachers to reflect on their practice. While a majority of surveyed teachers expressed that the PLCs were not equally useful to all teachers, most of the interviewed teachers expressed positive views of the PLCs. They felt they were able to share resources, collaborate, gain confidence, and improve their science programs. Although there were many benefits, the interviewed teachers expressed a number of negative aspects to their PLCs. These included a lack of focus, too many voices, administrative take over, lack of time, and too much structure.

Summary

This section offered a glimpse at the ternary approach needed for implementing inquiry in classrooms: the use of inquiry curriculum kits, addressing teacher beliefs, and providing effective professional development. The selected studies showcased how each of these can lead to successful implementation and identified possible barriers to that implementation. The next section will examine research on teacher experience that is phenomenological in nature and will identify the gap this dissertation serves to fill.

Phenomenological Research and Science Education

Research on science teachers and inquiry is primarily qualitative in nature, using interviews, observations, and document analysis to come to know the intersection between teachers' instructional experiences and their enactment of inquiry in the classroom. Implementing inquiry and teaching science is a deeply personal process: complex interactions occur between the teacher's beliefs, socio-environmental factors, available resources, and their students (Baird, 1999; van Driel, Berry, & Meirink, 2014). Coming to know this process (i.e. experience) can be found through a phenomenological methodology. However, few studies on science teachers and inquiry are phenomenological.

Østergaard, Dahlin, and Hugo (2008) completed a comprehensive review of phenomenological research within science education. They first offer a phenomenological critique of science education: a gap exists between the lifeworld of the student and the scientific world. This gap leads to difficulty in learning science. This seems perplexing, as science, by its very nature, is an exploration through the lifeworld of the learner. They experience their lifeworld, learn from that experience, and share that experience with others (and consequently become part of the lifeworld of others). Yet, how students are taught science seems to be anything but phenomenological: students are taught that science is separate from their lifeworld. The authors offered learning science phenomenologically as a way to close this gap.

They organized the selected studies into three categories: phenomenology of science education, phenomenology in science education, and the integration of phenomenology into science education research. Of most importance to this dissertation is the phenomenology of science education. They defined it as, "the processes and activities of teaching and/or learning science [that] are understood and analyzed from a phenomenological point of view" (p. 99). This allows researchers to examine what happens within the teaching and learning of science. Only two studies were found that investigated the phenomenology of teaching science.

The first study by Baird (1999) focused on science teachers' experience of teaching. The purpose of his study was twofold: to phenomenologically understand science teaching and to explore if the essence of teaching changes or remains consistent over time. To meet these purposes, Baird asked 12 secondary science teachers to fill out a monthly reflection on their personal lived experiences over the previous month. There were four questions on the form (p. 77):

1. What is it, to be a science teacher?
2. What is science teaching?
3. What is the most important pay-off in science teaching?
4. What is the most important cost, or worst aspect, of science teaching?

The teachers did not consistently fill out the forms and the detail in responses varied. Baird offered this is indicative of how reflective—or retrospective—teachers are on their practice. In other words, those that are more retrospective take the time to reflect on their teaching and write more detailed responses.

Interpreting the findings, Baird (1999) identified two foci: the students and the task of teaching. The students were the primary focus as they were central to teachers' responses of challenges, benefits, and negative aspects of teaching. All of the teachers offered ways students made teaching science an important-pay off and as a cost to teaching. For example, teachers noted how they enjoyed watching their students grow but offered that it can be difficult to ignite their enthusiasm.

The second focus is on the task of teaching. Baird (1999) said this is consequential to the focus on students. He did not elucidate as to why the task is consequential, but it is inferred that the task of teaching cannot exist without the students. The tasks were contextualized within teacher and student. The teacher context focused on competency, organization, and management. The student context focused on getting through to the students, challenging the students, working with the students, and making science relevant for the students.

At the conclusion of the data collection, Baird (1999) added one item to the monthly questionnaire: "what has answering the five questions above made me do/think about?" (p. 77). All of the teachers responded that the phenomenological reflections were worthwhile. Some teachers commented how the reflections helped them look at their aims with teaching science and where they could grow as an educator. For some, the reflections served as a way to validate what they did in their classrooms, while others realized how serious their concerns about teaching were.

The previous summary of findings showed how Baird (1999) met the first purpose of his study. The second purpose was to see if the essence of teaching changed over time. Baird demonstrated that there is change by showcasing two teachers' responses over a several month period. One, a beginning science teacher, started enthusiastic about his job. But over a period of 18 months he developed a cynical attitude towards teaching, experienced teacher burn out, and lost his aim of teaching—originally it was focused on students but later transitioned to financial reasons. Two years after the study, this teacher left his position. The other teacher had been teaching for 6 years. Analyzing her forms over a 7-month period, Baird found there was change in how she viewed teaching science as a student-centered, rather than teacher-centered, subject.

The second study by Dahlin (2002) examined science student teachers' conceptions of the nature of science[1]. Dahlin's (2002) framework for this study is based on ontological reversal. He put forth that scientific theories, models, equations, and so on take on a life of their own such that they become disassociated from the senses that created them. That is, the theories (i.e. abstract concepts) become part of the experience of science rather than engaging the senses that lead to the discovery of the theories.

To demonstrate this point, he discussed the theory of light. The modern theory is inclusive and exclusive of what is sensed: only a portion of the electromagnetic spectrum is visible. To understand the theory, a student must go beyond the sensed and consider the abstract reality of massless photons, waves, and so on. Yet, the discovery of the theory is initially rooted in sensing visible light and feeling the effects of light. He wanted to know what his science student teachers thought of this in regards to the nature of science. Which is a scientific theory: one that is an abstract conception, or one that is rooted in what is sensed?

He presented his student teachers with Newton's and Goethe's theories on light. Newton's theory consisted of white light being composed of all colors, colors arising from light refracting through a prism, theories explaining beyond the observed phenomenon, and the observer as a passive onlooker of the phenomenon. Goethe's theory consisted of

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[1] This study was published in Swedish. I was able to obtain an English translation, but there was no attribution to who translated it.

white light being simple and composed of no other colors, colors arising from the interaction between light and darkness, theories existing as the facts of the senses (i.e. there is nothing beyond the phenomenon as the beyond is merely the representation of the senses), and the researcher as an active participant in the phenomenon.

A majority of his students said that Newton's theory is scientific and Goethe's theory is not. Those who argued for Newton said his theory was scientific as it sought to explain beyond the observed phenomenon. If it can simply be observed, then it isn't a scientific theory as that's just how it is: no explanation is needed. Those who said Goethe's theory was scientific argued that what Goethe did was science in itself: how he engaged in experiencing light is science, therefore how he explained light as an interaction between light and dark is a theory.

From the student's explanations, Dahlin (2002) concluded that their view of science has become disconnected from their senses. Those who supported Newton argued that science occurs on a conceptual, abstract level. These students seemed not to realize the concepts are born from an experience of a phenomenon: concepts are not simply part of the lifeworld they are born from it. In contrast, those who supported Goethe recognized that his theory is rooted in sense experiencing. Dahlin (2002) goes on to connect this back to science teachers: if only the abstract conceptual world is science, then what is to stop teachers from brushing aside science-as-sense-experiencing often engaged by children? Would this then not lead educators to focus on science as concept rather than as practice? By having his student teachers focus on the phenomenological nature of science, he believed these teachers would see the benefit of using inquiry in their classrooms.

Additional phenomenological studies of science teachers and their experiences of teaching science have been conducted by Sadler (2006) and Dreon (2012). Sadler's study focused on pre-service science teachers' experience of student teaching science. His analysis of interviews, group discussions, and written reflections revealed five themes: challenges, successes, supports, knowledge gains, and ideal teaching. Many of the pre-service teachers experienced praxis shock (Kelchtermans & Ballet, 2002), in which their idealized notions of science education were deemed unattainable and resulted in pragmatic approaches. When asked to describe their ideal teaching, all of the pre-service teachers, except one, made statements in line with reform-based pedagogies.

Dreon's (2012) study included two participants who were science teachers with limited background in teaching science. The study found that the teachers' emotions and self-views influenced their use of inquiry. Anxiety was one such emotion experienced by both teachers. This anxiety arose from a lack of conceptual and content understanding. Inquiry was easier to implement when the content knowledge was more familiar. Further, how they perceived their students' reactions to inquiry affected their use of inquiry. When the students were struggling with an open-ended inquiry, one of the teachers chose to give the students the answer rather than allow them to continue to struggle. Students also provided feedback that some of the inquiry activities were frustrating and a waste of time. One teacher interpreted this as negative feedback about herself. This interpretation could later be detrimental to future inquiry lessons.

The four reviewed phenomenological studies show how the experience of teaching affects the teacher's implementation (or non-implementation) of inquiry. Baird's (1999) study revealed that the subject of science was taken for granted and teachers may lose sight of the goal of teaching science in its Deweyan, inquiry-focused ideals. Dahlin's (2002) study conveyed that science teachers may disconnect the phenomenological (i.e. inquiry) aspect of science from learning as it is not as important as the abstract, conceptual part of science. Sadler's (2006) study offered student teachers' conceptions of science teaching are met with the reality of classroom constraints. The pre-service teachers enter a survival mode in which the ideal is not attainable until they can navigate the various factors that affect their initial years of teaching. Dreon's (2012) study made known how the teachers' emotions are a factor in how teachers implement inquiry in their classrooms. Each of these studies offers ways to improve teacher education and preparedness for implementing inquiry in the classrooms.

Gap in the Literature

It is clear that research on science teachers, inquiry, and teacher beliefs is abundant. These studies have been implemented in a variety of ways: quantitatively through surveys and self-rating instruments, and qualitatively through observations, field reports, and interviews. Although phenomenological research has been conducted in regards to teachers and science education, limited studies have focused on the experience of teaching inquiry. Only two were found to be a phenomenological study of how teachers experience teaching through inquiry. Neither of these studies has looked at the how veteran science teachers experience teaching through inquiry; nor have any studies done this in light of the recent adoption of NGSS.

This dissertation addressed science teachers with a longer history of science teaching experience and looked at their experiences with teaching an inquiry-based curriculum. Therefore, this study added to the limited phenomenological research on how science teachers experience inquiry curriculum implementation.

References

Abell, S.K. (2007). Research on science teacher knowledge. In S. Abell & N.G. Lederman (Eds.), *Handbook of research on science education* (pp. 1105-1149). Mahwah, NJ: Lawrence Erlbaum Associates.

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

American Association for the Advancement of Science. (1993). *Benchmarks for Science Literacy*. New York: Oxford University Press.

Anderson, C. W. (2007). Perspectives on science learning. In S.K. Abell & N.G. Lederman (Eds.), *Handbook of research on science education* (pp. 3-30). Mahwah, NJ: Lawrence Earlbaum Associates.

Anderson, R. D. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education, 13*(1), 1-12.

Appleton, K. (2007). Elementary science teaching. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of Research on Science Education* (pp. 493-535). Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.

Asay, L. D., & Orgill, M. (2010). Analysis of Essential Features of Inquiry Found in Articles Published in The Science Teacher, 1998–2007. *Journal of Science Teacher Education, 21*(1), 57-79.

Baird, J.R. (1999). A phenomenological exploration of teachers' views of science teaching. *Teachers and Teaching: Theory and Practice, 5*, 75-93.

Bush, V. (1945). *Science: The endless frontier.* Washington, D.C.: United States Government Printing Office.

Breslyn, W. & McGinnis, J.R. (2011). A comparison of exemplary biology, chemistry, earth science, and physics teachers' conceptions and enactment of inquiry. *Science Education, 96*(1), 48-77.

Bybee, R. W. (1993). *Reforming science education: Social perspectives and personal reflections*. New York: Teachers College Press.

Capps, D. K., Crawford, B. A., & Constas, M. A. (2012). A review of empirical literature on inquiry professional development: Alignment with best practices and a critique of the findings. *Journal of Science Teacher Education, 23*(3), 291-318.

Cheek, D. (1992). *Thinking constructively about science, technology, and society education.* Albany, NY: State University of New York Press.

Cochran, K. F., DeRuiter, J. A., & King, R. A. (1993). Pedagogical content knowing: An integrative model for teacher preparation. *Journal of Teacher Education, 44*(4), 263-272.

Crawford, B. (2007). Learning to reach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching, 44*(1), 613-642.

Crawford, B. (2014). From inquiry to scientific practices in the science classroom. In N.G. Lederman & S.K. Abell (Eds.), *Handbook of research on science education* (pp. 515-541). New York, NY: Routledge.

Cronin-Jones, L.L. (1991). Science teacher beliefs and their influence on curriculum implementation: Two case studies. *Journal of Research in Science Teaching, 28*(3), 235-250.

Dahlin, B. (2002). *Den tunga vetenskapen. Lärarstuderandes uppfattningar av naturvetenskap med kontroversen mellan Goethes och Newtons optik som utgångspunkt* [Heavy science. Teacher students' conceptions of science with the controversy between Goethe's and Newton's optics as frame of reference]. Karlstad, Sweden: Karlstad University Studies.

Dias, M., Eick, C.J., & Brantley-Dias, L. (2011). Practicing what we teach: A self-study in implementing an inquiry-based curriculum in a middle grades classroom. *Journal of Science Teacher Education, 22*(1), 53-78.

Dickerson, D., Clark, M., Dawkins, K., & Horne, C. (2006). Using science kits to construct content understandings in elementary schools. *Journal of Elementary Science Education, 18*(1), 43-56.

Dimopoulos, K., & Koulaidis, V. (2003). Science and technology education for citizenship: The potential role of the press. *Science Education*, *87*(2), 241-256.

Dreon, O. (2012). Being in the hot spot: A phenomenological study of two beginning teachers' experiences enacting inquiry science pedagogy. *Teachers and Teaching: Theory and Practice, 18*(3), 297-313.

Education Development Center, Dow, P. B., & Bruner, J. S. (1968). *Man, a course of study*. Washington, D.C: Curriculum Development Associates.

Flick, L. B. (2006). Developing understanding of scientific inquiry in secondary students. In L. B. Flick & N. G. Lederman (Eds.), *Scientific inquiry and nature of science: Implications teaching, learning, and teacher education* (pp. 157–172). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Forbes, C.T., & Davis, E.A. (2010). Beginning elementary teachers' beliefs about the use of anchoring questions in science: A longitudinal study. *Science Education, 94*(2), 365-387.

Fullan, M. (2007). *The new meaning of educational change* (4th ed.). New York, NY: Teachers College Press.

Greene, J. C. (2001). Mixing social inquiry methodologies. In V. Richardson (Ed.), *Handbook of Research on Teaching*, 4th ed. (pp. 251-258). Washington, DC: American Educational Research Association.

Hawley, W.D., & Valli, L., (1999). The essentials of effective professional development. In L. Darling-Hammond & G. Sykes (Eds.), *Teach as the learning profession: Handbook of policy and practice* (pp. 127-150). San Francisco, CA: Jossey-Bass Publishers.

Houston, L.S., Faster, B.J., & Ledbetter, C.E. (2008). An evaluation of elementary school science kits in terms of classroom environment and student attitudes. *Journal of Elementary Science Education, 20*(4), 29-47.

Ireland, J., Watters, J.J, ,Brownlee, J., & Lupton, M. (2014). Approaches to inquiry teaching: Elementary teacher's perspectives. *International Journal of Science Education, 36*(10), 1733-1750.

Johnson, C.C. (2006). Effective professional development and change in practice: Barriers science teachers encounter and implications for reform. *School Science and Mathematics, 106*(3), 150-161.

Jones, M.G., & Carter, G. (2007). Science teacher attitudes and beliefs. In S. Abell & N. Lederman (Eds.), *Handbook of research on science education* (pp. 1067–1104). Mahwah, NJ: Lawrence Erlbaum Associates.

Jones, M.T., & Eick, C.J. (2007). Providing bottom-up support to middle school science teachers' reform efforts in using inquiry-based kits. *Journal of Science Teacher Education, 18*, 913-934.

Jones, M. G., Gardner, G., Robertson, L., & Robert, S. (2013). Science professional learning communities: Beyond a singular view of teacher development. *International Journal of Science Education, 35*(10), 1756-1774.

Jones, M.G., & Leagon, M. (2014). Science teacher attitudes and beliefs: Reforming practice. In N.G. Lederman & S.K. Abell (Eds.), *Handbook of research on science education* (pp. 830-847). New York, NY: Routledge.

Kahle, J.B. (2007). Systemic reform: Research, vision, and politics. In Abell, S.K. & Lederman, N.G. (Eds.), *Handbook of research on science education* (pp. 319-343). Mahwah, NJ: Lawrence Erlbaum Associates.

Kali, Y., Linn, M. C., & Roseman, J. E. (2008). *Designing coherent science education*. New York: Teachers College Press.

Kang, N-H., Orgill, M., & Crippen, K.J. (2008). Understanding teachers' conceptions of classroom inquiry with a teaching scenario survey instrument. *Journal of Science Teacher Education, 19*(4), 337-354.

Kelchtermans, G., & Ballet, K. (2002). The micropolitics of teacher induction: A narrative-biographical study on teacher socialization. *Teaching and Teacher Education*, *18*(1), 105–120.

Keys, C. W. & Bryan, L.A. (2001). Co-constructing inquiry-based science with teachers: essential research for lasting reform. *Journal of Research in Science Teaching, 38*(6), 631-645.

Levitt, K. E. (2001). An analysis of elementary teachers' beliefs regarding the teaching and learning of science. *Science Education, 86*(1), 1-22.

Lerner, L.S., Goodenough, U., Lynch, J., Schwartz, M., & Schwartz, R. (2012). *The state of state science standards*. Retrieved from: http://files.eric.ed.gov/fulltext/ED528964.pdf

Lotter, C., Harwood, W. S., & Bonner, J. J. (2007). The influence of core teaching conceptions on teachers' use of inquiry teaching practices. *Journal of Research in Science Teaching*, *44*(9), 1318–1347.

Loucks-Horsley, S., Stiles, K.E., Mundry, S., Love, N., & Hewson, P.W. (2010). *Designing professional development for teachers of science and mathematics*. Thousand Oaks, CA: Corwin Press.

Luft, J.A., and P.W. Hewson. (2014). Research on teacher professional development programs in science. In N.G. Lederman & S.K. Abell (Eds.), *Handbook of research on science education,* 2nd edition, (pp. 889–909). New York, NY: Routledge.

Mansour, N. (2009). Science-technology-society (STS): A new paradigm in science education. *Bulleting of Science, Technology, & Society, 29*(4), 287-297.

Martin-Hansen, L. (2000). Defining inquiry: Exploring the many types of inquiry in the science classroom. *The Science Teacher, 69*(2), 34-37.

Mason, C. L. (1999). The TRIAD approach: A consensus for science teaching and learning. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining Pedagogical Content Knowledge* (pp. 277-292). Dordrecht, The Netherlands: Kluwer Academic Publisher.

National Commission on Excellence in Education (1983). *A nation at risk: The imperative for educational reform*. Washington, D.C.: Government Printing Office.

National Research Council (1996). *National science education standards*. Washington, DC: National Academy Press.

National Research Council. (2000). *Inquiry and the national science education standards: A guide for teaching and learning*. Washington, DC: National Academy Press.

National Research Council (2012). *A framework for K-12 science education: Practice, crosscutting concepts, and core ideas.* Washington, DC: National Academy Press.

NGSS Lead States. (2013). *Next generation science standards: For states, by states*. Washington, D.C: National Academies Press.

Nisbett, R., & Ross, L. (1980). *Human inference: Strategies and shortcomings of social judgement.* Englewood Cliffs, NJ: Prentice Hall.

No Child Left Behind (NCLB) Act of 2001, 20 U.S.C.A. § 6301 *et seq.* (West 2003)

Ogens, E.M., & Koker, M. (1995). Teaching for understanding: An issue-oriented science approach. *The Clearing House: A Journal of Educational Strategies, 68*(6), 343-345.

Osborne, J. (2014). Teaching scientific practices: Meeting the challenge of change. *Journal of Science Teacher Education, 25*(2), 177-196.

Østergaard, E., Dahlin, B., & Hugo, A. (2008). Doing phenomenology in science education: A research review. *Studies in Science Education, 44*(2), 93-121.

Ozel, M., & Luft, J. A. (2013). Beginning Secondary Science Teachers' Conceptualization and Enactment of Inquiry-Based Instruction. *School Science & Mathematics*, *113*(6), 308-316.

Pajares, M.J. (1992). Teachers' beliefs and education research: cleaning up a messy construct. *Review of Education Research, 62*(3), 307-332.

Powell, J.C., & Anderson, R. D. (2002). Changing teachers' practices: Curriculum materials and science education reform in the USA. *Studies in Science Education, 37,* 107-136.

Remillard, J.T. (2005). Examining key concepts in research on teachers' use of mathematics curricula. *Review of Educational Research, 75*(2), 211-246.

Rokeach, M. (1968). *Beliefs, Attitudes, and Values: A Theory of Organization and Change*. San Francisco, CA: Jossey-Bass, Inc.

Sadler, T.D. (2006). "I won't' last three weeks": Preservice science teachers reflecting on their student-teaching experiences. *Journal of Science Teacher Education 17*(3), 217-241.

Savasci-Acikalin, F. (2009). Teacher beliefs and practice in science education. *Asia-Pacific forum on Science Learning and Teaching, 10*(1), 1-14.

Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Simmons, P.E., Emory, A., Carter, T., Finnegan, B., Crockett, D., Richardson, L.,…Labuda, K., (1999). Beginning teachers: Beliefs and classroom actions. *Journal of Research in Science Teaching, 36*(8), 930-954.

Smithsonian Institution (2013). *Investigating biodiversity and interdependence*. Burlington, NC: Carolina Biological Supply Company.

Smithsonian Institution (2015). *Electricity, waves, and information transfer*. Burlington, NC: Carolina Biological Supply Company.

Sparks, D. (2002). *Designing powerful professional development for teachers and principals.* Oxford, OH: National Staff Development Council.

Stofflett, R.T. (1994). The accommodation of science pedagogical knowledge: The application of conceptual change constructs to teacher education. *Journal of Research in Science Teaching, 31*(8)*,* 787-801.

Stoll, L., Bolam, R., McMahon, A., Wallace, M., & Thomas, S. (2006). Professional learning communities: A review of the literature. *Journal of Education Change, 7*(4), 221-258.

Supovitz, J.A., Mayer, D.P., & Kahle, J.B. (2000). Promoting inquiry-based instructional practice: The longitudinal impact of professional development in the context of systemic reform. *Educational Policy*, 14(3), 331-356.

Supovitz, J.A. & Turner, H.M. (2000). The effects of professional development on science teaching practices and classroom culture. *Journal of Research in Science Teaching, 37*(9), 963-980.

Sykes, G. (1999). Teacher and student learning: Strengthening their connection. In L. Darling-Hammond & G. Sykes (Eds.), *Teach as the learning profession: Handbook of policy and practice* (pp. 127-150). San Francisco, CA: Jossey-Bass Publishers.

Tobin, K., & McRobbie, C.J. (1996). Cultural myths as constraints to the enacted science curriculum. *Science Education, 80*(2), 223-241.

Thompson, C. L., & Zeuli, J. S. (1999). The frame and the tapestry: Standards-based reform and professional development. In L. Darling-Hammond & G. Sykes (Eds.), *Teaching as the learning profession: Handbook of policy and practice* (pp. 341-375). San Francisco, CA: Jossey-Bass.

Van Dijk, E.M., & Kattman, U. (2007). A research model for the study of science teachers' PCK and improving teacher education. *Teacher and Teacher Education, 23*(6), 885-897.

van Driel, J.H, Berry, A., & Meirink, J. (2014). Research on science teacher knowledge. In N.G. Lederman & S.K. Abell (Eds.), *Handbook of research on science education* (pp. 848-870). New York, NY: Routledge.

Waters, J.T., & Marzano, R.J. (2006). *School leadership that works: The effect of superintendent leadership on student achievement.* Aurora, CO: Midcontinent Research for Education and Learning.

Wilson, S., & Berne, J. (1999). Teacher learning and the acquisition of professional knowledge: An examination of the research on contemporary professional development. *Review of Research in Education, 24*(), 173-209

Yager, R.E. (1996). *Science/technology/society as reform in science education*. Albany, NY: State University of New York Press.

Young, B.J., & Lee, S.K. (2005). The effects of kit-based science curriculum and intensive science professional development on elementary student science achievement. *Journal of Science Education and Technology, 14*(5/6), 471-481.

Chapter 3:

Methodology

The purpose of this dissertation was to describe how a cohort of junior high and middle school science teachers experience the implementation of an inquiry-based curriculum. Revealing this experience in light of each teachers' values and beliefs was done through a phenomenological methodology. As teachers integrate their beliefs and values into their lessons (Jones & Carter, 2007; Bryan, 2012), it is important to select a methodology that would focuses on the experience of the teacher. Phenomenology reveals this experience and how the experience has been affected by teachers' values and beliefs.

Phenomenology offers a gateway to understand how individuals experience reality, which is often different than what reality truly is (Gallagher, 2012). Gallagher (2012) explains this using an analogy of a glass window: when we look at the world through a window, the window affects how we view that world. If the window had a slight tint to it, the world would appear darker than it is. If the window is translucent, we could not discern specific shapes, but see changes in light. Much as a window affects our view of the world, our own experience in the world affects how we see reality and how we further experience it.

In this chapter I discuss how I conducted my research. First, I provide background on phenomenology. Then, I share my own experience with implementing science inquiry as that is part of the phenomenological process. Finally, I describe the plan for conducting this study: how I found my co-researchers (i.e. research participants), how I collected the data, how I ensured the trustworthiness of the data, and how I analyzed and interpreted the data.

Phenomenology

Husserl, recognized as the founder of phenomenology (Moustakas, 1994), was critical of scientism. Scientism is the belief that science is able to answer all questions and is an authoritative source of knowledge (Gallagher, 2012). Husserl (1970) challenged scientism, or what he called *natural thinking*, as science is undergirded by human consciousness. He did not reject science; rather he wanted to assert that our understanding of the world is grounded in our conscious, thus being higher in order to science (Gallagher, 2012). As our conscious affects how we perceive the world, he offered phenomenology as a way to understand our experiences. Husserl (1970) asked, "how can we be sure that cognition accords with things as they exist in themselves, that it 'gets at them'?" (p. 1). In other words, he asked how could we observe the true world when our ability to observe is filtered and affected by our cognition or conscious? Husserl wanted a way to describe the way things are as they appear in our conscious. As Gallagher (2012) put it, "the way things appear in conscious experience may be very different from the way things actually are in reality" (p. 8).

To do this, Husserl proposed that researchers must understand the essence of a phenomenon. The essence is the "set of invariant properties lying underneath the subjective perception of individual manifestations of that type of object" (Smith, Flower, Larkin, 2012, p. 14). That is, how we experience some phenomenon—be it a physical object or event—is subjected to our own values and beliefs of that phenomenon and our prior experiences. For example, if I were to show a picture of a cabin to someone, they might describe it as being a home in a wooded area. Perhaps they will recall their own moments of having campfires or week-long vacations in which they disconnect from our modern world. If I were shown a picture of the cabin where I spent my summers, I would recall many wonderful experiences with my cousins, learning how to fish, spending countless hours swimming, and having conversations with my family that influenced how I think about the world. That cabin is not merely a cabin; it is a component of my life. The memories are part of that subjectivity that Husserl seeks to discover through phenomenology.

van Manen (1984) said “phenomenological research, unlike any other kind of research, makes a distinction between appearance and essence, between the things of our experience and that which grounds the things of our experience” (p. 41). Thus, the essence is more than a simple description of the experience. The essence is “something [that] is construed so that the structure of a lived experience is revealed to us in such a fashion that we are now able to grasp that nature and significance of this experience in a hitherto unseen way” (p. 43).

Clarifying this idea, Sokolowski (2002) wrote phenomenology is “the study of human experience and of the ways things present themselves to us in and through such experience” (p. 2). His definition makes clear the importance of the presentation of experience, or what he called the “problem of appearances” (p. 3). The problem is how the appearance—or how we experience some phenomenon—changes as it propagates through a medium. This is quite equitable to the children’s game telephone: as the message is passed from one child to another, the message becomes distorted based on how they heard and understood the message. Just as some phenomenon is experienced by an individual, how they experience will be influenced by what the experience has passed through, including the individual themselves. In other words, phenomena are contextualized within a variety of situations and factors (e.g. historical, socioeconomical, ideological).

Heideggar, a student of Husserl, offered a slightly different view on phenomenology. Heideggar's focus was on the hermeneutic—or interpretative—aspects of phenomenology. Hermeneutics was developed as a method of investigating the "structures of reading and interpreting texts from the past" (Sokolowski, 200, p. 224). This focus led to Heideggar's critique of phenomenology: as phenomenology uses language, language itself is going to contain uncontrolled biases (Gallagher, 2012). For example, vocabulary is contextualized by historic events and individual beliefs. To demonstrate this, consider the word *theory* as used by a scientist compared to a non-scientist. Just as language is bound in context, Heideggar contended that humans were objects thrown into a world of relationship and language. This refers to intersubjectivity, or the "shared, overlapping, and relationship nature of our engagement in the world" (Smith, Flowers, & Larkin, 2012, p. 17). Thus, the purpose of phenomenology is not only to describe how individuals experience a phenomenon, but also to interpret a meaning of that experience with the individual.

In the pilot study for this dissertation, I used phenomenological methods to describe a science teacher's experience in developing an inquiry-based curriculum. The teacher and I found that the essence of the experience was liberation. Designing a new curriculum allowed her to incorporate her beliefs and values about science education. Prior to this, she experienced pushback from others in her department. They wanted to maintain a traditional, teacher-centered framework of science. Phenomenological methods were the reason why she and I were able to reveal the essence of her experience. Phenomenology offers a deeper perspective of the experience; it goes beyond the basic description. It allows us to know their experience of reality rather than how an outsider would view it. It allows us to briefly live a moment in their shoes.

This dissertation sought to describe those experiences teachers have in adopting inquiry-based curriculum. I wanted to know what their version of reality is. How did their own experiences affect how they experience this phenomenon? How did they incorporate their values and beliefs into the inquiry kits? How did they react to science education reform? Why were their reactions and experiences this way? What meaning did they make of this experience? Phenomenology provides the methods needed to answer these questions.

Methods

Revealing this experience and how it has been influenced is done through certain phenomenological methods. Although Husserl and Heideggar did not offer specific methods of how to conduct phenomenological research, their writings focus on some key ideas: most notably *epoché,* or *bracketing,* and *reduction*.

The idea of epoché is to recognize our own intersubjectivities of a phenomenon. As an example, if a scientist were to see a container labeled *dihydrogen monoxide*, they would recognize that as the formal chemical name of water. To a non-scientist, they may associate this with fear: they may connect term *monoxide* to *carbon monoxide* and think of a dangerous gas; perhaps they will see the chemical name and think that it is an artificial creation by humans as the term is unfamiliar to them. The point is that phenomenologists must recognize their own theories and beliefs about a phenomenon and suspend, or bracket them (Gallagher, 2012). A phenomenologist must set aside their natural thinking of an experience to be left with their consciousness of the experience. This will allow a phenomenologist to access the essence of the experience.

Accessing the essence is done through *reduction*. In reduction we reflect on the experience as it is experienced (Gallagher, 2012). That is, the reduction seeks to provide a complete description of a phenomenon's "essential constituents, variations of perceptions, thoughts, feelings, sounds, colors, and shapes" (Moustakas, 1994, p. 34). The reduction leads us away from the natural thinking that Husserl criticized (Sokolowski, 2000).

Getting to the point at which one could begin to analyze an experience phenomenologically takes significant work. Moustaktas (1994, pp. 103-104) identified seven steps in phenomenological studies:

1. Forming a topic and questions that have both social meaning and personal significance;
2. Conducting a comprehensive review of the literature;
3. Constructing a set of criteria to locate appropriate co-researchers;
4. Informing co-researchers of the research process (i.e. following IRB protocols);
5. Developing a set of questions or topics to guide the interview process;
6. Conducting and recording lengthy person-to-person interviews that focuses on a bracketed topic and question;
7. Organizing and analyzing the data.

van Manen (1990) offered steps to produce descriptions of the lived-experience. He recommended (pp. 60-67):

1. You need to describe the experience as you live(d) through it avoiding as much as possible causal explanations, generalizations, or abstract interpretations;
2. Describe the experience from the inside as it were; almost like a state of mind: the feelings, the mood, the emotions, etc.;
3. Focus on a particular example or incident of the object of the experience: describe specific events, an adventure, a happening, a particular experience;
4. Try to focus on an example of the experience which stands out for its vividness, or as it was the first time;
5. Attend to how the body feels, how things smell(ed), how they sound(ed), etc;
6. Avoid trying to beautify your account with fancy phrases or flowery terminology.

Although van Manen stated his recommendations in the second person, it is applicable to the third person: his, her, and their. Describing the experience goes beyond a simple re-telling of the individual's experience. Analysis is necessary to reach the meaning of the experience. This is typically done through a) reading and re-reading transcripts of those interviewed, b) noting and coding those transcripts, c) developing emergent themes from the codes, and d) searching for connections amongst those themes (Smith, Flowers, and Larkin, 2012).

I used combinations of van Manen's (1990), Moustakas' (1994), and Smith, Flowers, and Larkin's (2012) phenomenological research methods in conducting this dissertation. These research methods lead to well-developed and thought out research questions, rich, detailed descriptions of the co-researchers' experiences, and thorough analysis that results in an interpretation of the experience. I used these same methods when I conducted a pilot study for this dissertation. The pilot study consisted of three interviews (discussed later in this chapter) that resulted in comprehensive descriptions of the co-researcher's experience in designing an inquiry science curriculum. After noting, coding, and identifying themes in the transcripts, the co-researcher agreed with the analysis of her experience.

This phenomenological study began with a reflection of my own experience with implementing science inquiry curriculum. I did this to show that my study is of personal significance and to bracket my own natural attitudes. The previous chapters have already established the social meaning for this study. After this reflection of my experience, I will explain how I located co-researchers, how I collected data, and how I analyzed that data.

My Experience with Science Inquiry

My love of science began when I was a child. I recall this moment on a trip to the Chicago Museum of Science and Industry with my family. We were in the museum when my brothers and sister ran ahead of me, smiling with excitement. I stayed behind, frozen in fear. My dad was a few feet ahead of me, telling me there was nothing to be afraid of. I was seven and the unrealistic fears of what could happen raced through my mind. *What if it tries to eat me? Can I get lost inside it? What if I can't swim in the blood?*

My dad took my hand and walked me to the entrance of the model heart. He smiled, giving me reassurance that everything would be all right. As we walked into the model, my fears disappeared.

I was mesmerized by the inside of the heart. My dad pointed out the parts and explained how everything worked. Full of excitement, we began exploring everything we could at the Museum of Science and Industry. From seeing the chicks hatch to going on the coalmine tour, I was captivated by it all. While I did not realize it then, it was on this day that I fell in love with science.

Since that day I have always been fascinated and curious about my environment. Science has allowed me to explore the world. It makes me open my eyes to observe what I would otherwise not see. It makes me think critically. It makes me challenge what I know and be critical of what I am told. It is not stagnant. It is an ever-changing discipline. This is what I love about science. This is what made me want to be science teacher: I loved it so much that I wanted to share this with children.

I earned my bachelor of science in elementary education from Illinois State University in May 2006. In the fall of 2006, I started teaching seventh grade science. My first few years of teaching science relied heavily on traditional teaching models: I often lectured, provided cookbook science activities, and did not allow my students to ask questions for investigations, design procedures, grapple with messy data, nor reach their own conclusions. My students had to reach the answers that were already known. Their skills were honed on replicating results rather than developing their scientific literacy. How I taught science was not reflective of how science was done. It was, however, reflective of how I learned science in school.

To counteract this, I enrolled in a Master of Science in Science Education graduate program at DePaul University in the spring of 2009. The program was designed to help science teachers use inquiry in their classrooms. While in the program I frequently reflected on my own teaching: how could I move away from traditional teaching and toward inquiry, how could I let go of the control I have of the classroom, how do I find the resources necessary for implementing inquiry?

I struggled with the pragmatic side of inquiry. Although I participated in inquiry lessons at DePaul, developed inquiry lessons, and was evaluated teaching inquiry lessons, trying to translate inquiry into actual practice was difficult. The curriculum I used in my classroom was not based in inquiry. It was based in traditional models: lecture, confirmation activities, and a focus on the memorization of content over the practices of science.

My solution was to slowly introduce it into my teaching. I structured my lectures so they took shorter amounts of time and left time for students to engage in data collection and analysis. I sought additional curriculum materials and began creating a patchwork of lessons from various sources. I revamped our cookbook activities so the students were not simply matching outcomes: they were reaching their own and attempting to conclude what they could learn from those outcomes.

I graduated in 2011 and found that I had a much better understanding of inquiry. Yet, I was still struggling on integrating it into most of my curriculum. Fortunately, my school district announced it was placing our science curriculum under redesign. Our consultant restructured our curriculum such that it focused on scientific practices taught through various content. While the content was important, the scientific practices were the overarching theme found in all our units. Our students would be expected to know how to design investigations, collect and analyze data, question findings, and construct arguments: practices consistent with reform efforts in science education.

To ensure this outcome was achieved, our consultant provided us with several curriculum kits to review. These kits included SEPUP, FOSS, and STC. Our grade level eventually adopted two units from STC. Our training on these units allowed us to see how they are inquiry-based, how the lessons focus on scientific practices, and how to carry out the lessons. I remember when I was given a copy of the teacher's manual. As I reviewed the lessons I thought how exciting it would be to teach this way! The first lesson in the book was using an authentic data source to plot points on a map, analyze the points for patterns, and offer explanatory hypotheses for the patterns that were discovered.

Yet, when it came time for the new curriculum to be implemented it was anything but a success. It was a struggle. It was difficult to plan the pacing for the lessons, even though the curriculum came with recommended pacing. I was replacing some lessons with my own, adding content where I felt the textbook didn't deliver enough information, and revising how investigations were designed to match what I felt were better ideas for activities.

I found that I was battling the curriculum over my own identity: this curriculum was not mine. It was not the curriculum that I had crafted in the previous 3-4 years. It was entirely someone else's; I had no ownership in it. I wanted desperately to change it. As I reflect on this now, I realize that this came about from my own familiarity with the curriculum topics. The unit addressed the exploration of life from the microscopic to the macroscopic. Because I was familiar with this and had taught it for so many years, it was hard to let go of my old habits. This curriculum represented the final hurdle to moving all of my philosophy and practice into inquiry.

Overcoming this hurdle was done with an STC unit in earth science. The unit was on catastrophic events. I was not familiar with this at all. Prior to our curriculum redesign, earth science was taught from understanding minerals, rocks, change, and geologic history. The STC unit focused on what causes small and large scale changes in the earth's geosphere and atmosphere. This new content forced me to follow the curriculum closely. I stayed as true to the lessons and pacing as I could. And, perhaps unsurprisingly, I loved the unit.

I was in love with how inquiry focused the lessons were. I loved how the students got to design investigations and critique their own designs for collecting data. We would often extend lessons by a day or two so we could revisit the investigation and try to implement some of the changes. The students and I were aiming for obtaining data that would be hard to challenge. We wanted to engage these scientific practices. I had never observed this from students while teaching earth science. Usually earth science was the boring topic. Now they loved it as it was taught in a way that science is done.

This experience is the foundation for this dissertation. As I reflected on my own experience and what it meant to me, I had to wonder what it was like for other teachers. Every week I had the chance to meet with my department and discuss how we were experiencing the new curriculum. We all discussed our frustrations and celebrations. But, that was only a surface understanding of how they went through it. I wondered why we were insistent on keeping some of our older lessons: what was influencing us to do this? Why did we fully embrace some lessons and units but feel like others were not worth it?

This dissertation seeks to find answers to those questions. How do other science teachers experience the implementation of inquiry curriculum? How do their beliefs influence that experience? What is the essence of their experience?

Co-researcher (Participant) Recruitment

Having shown how this study is of personal significance, Moustakas (1994) contended that the researcher finds participants—or co-researchers—to participate in the study. In phenomenological studies this is done through purposeful sampling. This recruitment method allows for a researcher to select individuals that most closely match the purpose of study. The result is a selection of information-rich co-researchers (Patton, 2002) and will exclude individuals who are not well experienced in the focused phenomenon (Payls, 2008).

Criterion sampling was used for this study to obtain a purposeful sample. Criterion sampling involves recruiting cases that meet criteria in order to meet the objectives of the study. This study required participants who met the following criteria:

- Are a middle school or junior high science teacher,
- Use an inquiry-based science kit adopted as a result of a curriculum change, and
- Have undergone a curriculum change within the last 5 years

The first criterion is to mimic my own experience: I am a junior high science teacher and previously had experience teaching science in a middle school. Finding teachers who are in a similar background will allow me to better understand their experience. The second criterion is to meet the focus of this study: teachers who implement an inquiry-based science kit. The final criterion is reflective of changes that have occurred at a national level. Namely, the release of the Next Generation Science Standards. I focus on this as the Next Generation Science Standards are founded within an inquiry-framework of teaching and learning.

Smith, Flowers, and Larkin (2012) offered there is not right answer to how many co-researchers should be in a phenomenological study. As seen in the literature review, phenomenological studies in science education have ranged from two co-researchers (Dreon, 2012) to twelve (Baird, 1999). Smith, Flowers, and Larkin (2012) suggested that between three to six participants could be a reasonable sample size. I proposed having four co-researchers, one from each grade: fifth through eighth. However, in my recruitment process I did not recruit one teacher from each grade level as planned. This was due to an opportunity in which one of the teachers (Judy) had taught fifth grade and moved to sixth grade. Judy offered a unique perspective on changing science curriculum twice: once when changing from the old to new curriculum in fifth grade and changing between the new curriculums when she moved to sixth grade. I also recruited two eighth grade teachers, one of whom (Delores) was the original co-researcher in the pilot study for this dissertation. I was curious to see how her experience continued after she had designed the curriculum.

I recruited the four co-researchers for this study through professional contacts I have of other science educators. These educators and I have lived through the experience together by connecting through our professional network. Through e-mail, phone calls, and occasionally in person, we develop and share feedback on our lessons, give suggestions for improvement, and bounce new ideas off each other to see how they might work. The four recruited co-researchers met the three requirements for the study: they are all middle school and junior high teachers, they are all teaching science through kits, and they have undergone the adoption of the kits within the last five years. I e-mailed each of the teachers to request their participation and included the adult consent form that outlined information about the study and the rights they would have. Each co-researcher replied agreeing to be part of this study.

Table 3.1 provides background information on each of the four co-researchers participating in this study.

Table 3.1

List of Co-Researchers

Name (Pseudonym)	Years Teaching	Current Grade	New Curriculum Unit Providers
Judy	10	6th	5th grade: SEPUP 6th grade: STC Secondary
Elizabeth	18	7th	STC Secondary
Laura	7	8th	SEPUP NSTA Supplementary Materials
Delores	23	8th	SEPUP NSTA Supplementary Materials

Data Collection

The most common data collection method for phenomenological research is through the semi-structured interview (Moustakas, 1994; Smith, Flowers, & Larkin, 2012; Seidman, 2013). A semi-structured interview includes a list of planned questions and probes and allows for flexibility in asking unplanned questions (Gall, Gall, & Borg, 2006). The length of interviews ranges between 45 and 90 minutes. Smith, Flowers, and Larkin (2012) propose 45 to 90 minutes based on the topic being studied. Seidman (2013) sided on the 90-minute interview: it's not too short to lose on detail and it is not too long that the research and co-researcher feel like they are having to fill time.

Seidman (2013) and Creswell (2007) offered guidelines for doing phenomenological interviews. Seidman (2013) proposed three interviews: a life history, the pre-experience, and the post-experience. Creswell (2007) offered two questions for collecting data in phenomenological research: "What have you experienced in terms of the phenomenon?" and "what contexts or situations have typically influenced or affected your experience?" (p. 61). The interviews for this study are based on slightly modified version of these models.

For this dissertation, I conducted two interviews with each participant based on a modified version of Seidman's (2013) model. Originally three interviews were planned following Sediman's (2013) model. However, DePaul's Institutional Review Board stated that this would be too many interviews and accepted combining the first interview—the life history—with the second interview—the pre-experience. The then-third interview—the post-experience—remained unaffected. Combining the first two interviews together reduced the total number of interviews. However, it kept the proposed amount of interview time the same. A follow up interview through e-mail was scheduled with each co-researcher in the event clarification questions were needed. This interview was used with all co-researchers except Laura. Questions in the interview are based on Creswell's (2007) two core interview questions supported with several guiding and probing questions.

The first interview (Appendix A) focused on the history of the co-researcher: their educational background and influences in their philosophy, beliefs, and practices in education. It also focused on the teacher's experiences with her old curriculum: what was expected to be taught, how the teacher taught the lessons, and what the teacher felt were the strengths and weaknesses of the curriculum. This interview lasted just under 90 minutes for each participant. The second interview (Appendix B) was like the first interview in that the same questions are asked of the old curriculum but, instead, are asked on the new curriculum. This interview lasted just under 60 minutes for each participant. Each interview was audio-recorded and then transcribed verbatim into a word processor.

Although some phenomenological studies have employed more than one data source (e.g. using interviews, document analysis, and observations), it is argued that interviews are the strongest source of data in answering research questions. Pollio, Henley, and Thompson (1997) presented interviews in phenomenology as "an almost inevitable procedure for attaining a rigorous and significant description of the world of everyday human experiences as it is based and described by specific individual in specific circumstances," (p. 28).

Data Analysis

To understand the participant's experience, it is necessary to identify "significant statements, sentences, or quotes that provide an understanding of how the participant experiences the phenomenon" (Creswell, 2007, p. 61). This allowed me to provide a description of the participant's experience and find meaning within it. Each co-researcher's data was analyzed separately. This process began with several readings of the transcripts to familiarize myself with the data. After, the data was coded by summarizing significant text within the transcripts. The codes included frequent keywords, ideas, and phrases stated by the participant. For example, in her second interview Judy's shared an experience in taking an online class in chemistry. She felt the teacher was ignoring students' questions in the online forum. She stated "I always took it upon myself to go in and answer people's questions." This was coded as leadership, a need to be a teacher to other students, stepping up, and a shift of responsibility.

The transcripts were coded a second time to find any additional codes missed by the first coding. Next, the codes were analyzed several times to determine their relationships to each other. This was done by writing codes on Post-It notes and arranging them to reveal potential relationships. Several variations of this were done to identify possible themes. Finally, analyzing the relationship between these themes and the teacher's experiences revealed the essence of her experience. An example of this is shown in Figure 3.1. In this figure, a digital version of the Post-It notes used, Delores' codes were arranged to reveal different relationships.

Trustworthiness

As qualitative research is epistemologically different than quantitative research, issues concerning validity and generalizability are treated differently (Willis, 2007). Steps were taken to ensure the trustworthiness of the data, as outlined by Guba (1989).

First, while coding and analyzing data, I did my best to become aware of prejudices and beliefs that may influence my interpretation and understanding of the idea. Acknowledging these prejudices and beliefs can assist in keeping the validity of the data (Patton, 2002). I wrote my own beliefs and ideas of science education on a sheet of paper prior to reading and coding the interviews. This made me aware of them and helped me focus on the co-researchers' experiences rather than *my* interpretation of their experiences based on *my* experiences.

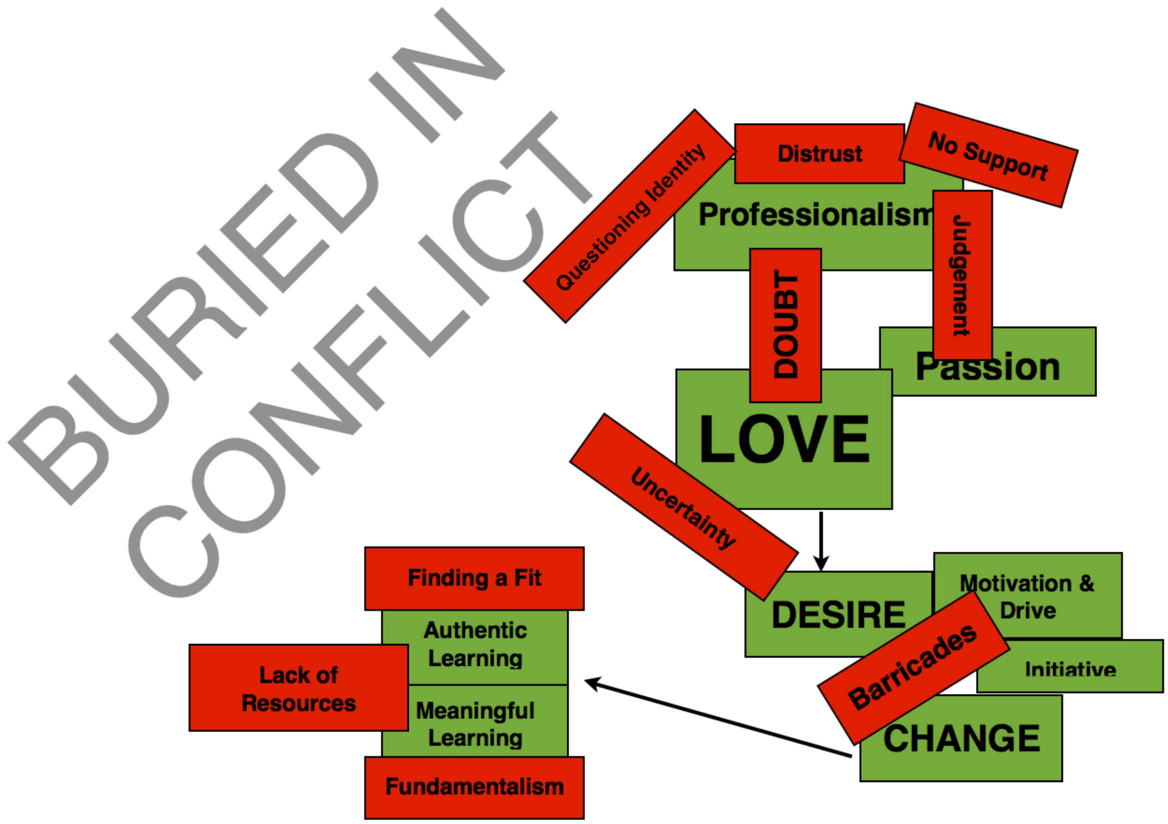

Figure 3.1 This is an example of an analytical diagram of the relationships between codes for Delores' data. Words that are in all capitals indicate more frequent occurrences of codes. Red boxes (overlapping other boxes) represent conflicts while green boxes represent the values

Second, the interviews were conducted in multiple parts as it allowed me to follow up on previous questions and information. Hearing the participant repeat information from previous interviews will add trust that the data collected were correct. At the beginning of the second interview I asked questions to each co-researcher based on what was stated in the first interview. Each co-researcher provided information that was identical to what they had previously stated.

Third, the transcripts of the interviews were shared with the participant for the explicit purpose of clarifying information or removing information that was inaccurate. I also summarized my understanding of the transcripts with the participant.

Fourth, the analysis of the data was shared with each co-researcher. Each individual co-researcher received the analysis of the findings based on their interviews. Each had the opportunity to provide feedback on the analysis. Each co-researcher felt the analysis was an accurate description of her experience. All co-researchers shared how they felt the analysis was an accurate representation of her experience and stated no revisions were needed.

Finally, the findings are presented with as many of the co-researchers' words as possible. This helped show my understanding and analysis of their experience is firmly rooted in their statements.

References

Baird, J.R. (1999). A phenomenological exploration of teachers' views of science teaching. *Teachers and Teaching: Theory and Practice, 5*, 75-93.

Bryan, L. (2012). Research on science teacher beliefs. In B.J. Fraser, K. Tobin, & C.J. McRobbie (eds.) *Second international handbook of science education*. (pp. 477-495). New York, NY: Springer.

Creswell, J. W. (2007). *Qualitative inquiry & research design: Choosing among five approaches*. Thousand Oaks: Sage Publications.

Dreon, O. (2012). Being in the hot spot: A phenomenological study of two beginning teachers' experiences enacting inquiry science pedagogy. *Teachers and Teaching: Theory and Practice, 18*(3), 297-313.

Gall, M.D., Gall, J.P., & Borg, W.R. (2006) *Education research: An introduction* (8th ed.). Boston, MA: Pearson.

Gallagher, S. (2012). *Phenomenology*. New York, NY: Palgrave Macmillan.

Guba, E.G. (1981) Criteria for assessing the trustworthiness of naturalistic inquiries. *Educational Communication and Technology Journal*, *29*(2), 75–91.

Husserl, E. (1970). *The idea of phenomenology*. The Hague: Martinus Nijhoff.

Jones, M.G., & Carter, G. (2007). Science teacher attitudes and beliefs. In S. Abell & N. Lederman (Eds.), *Handbook of research on science education* (pp. 1067–1104). Mahwah, NJ: Lawrence Erlbaum Associates.

Moustakas, C. E. (1994). *Phenomenological research methods*. Thousand Oaks, CA: Sage.

Palys, T. (2008). Purposive sampling. In L. M. Given (Ed.) *The Sage Encyclopedia of Qualitative Research Methods.* (Vol. 2). Los Angeles, CA: Sage. pp. 697-8.

Patton, M.Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage Publication.

Pollio, H.R., Henley, T.B., & Thompson, C.J. (1997). *The phenomenology of everyday life.* New York, NY: Cambridge University Press.

Seidman, I. (2013). *Interviewing as qualitative research: A guide for researchers in education and the social sciences*. New York, NY: Teachers College Press.

Smith, J. A., Flowers, P., & Larkin, M. (2012). *Interpretative phenomenological analysis: Theory, method and research*. Los Angeles, CA: SAGE.

Sokolowski, R. (2000). *Introduction to phenomenology*. New York, NY: Cambridge University Press.

van Manen, M. (1984). Practicing phenomenological writing. *Phenomenology + Pedagogy, 2*(1), 36-69.

van Manen, M. (1990). *Researching lived experience: Human science for an action sensitive pedagogy*. Albany, NY: State University of New York Press.

Willis, J. (2007). *Foundations of qualitative research: Interpretive and critical approaches*. Thousand Oaks: SAGE Publications.

Chapter 4:

Data and Findings

The purpose of this phenomenological dissertation is to describe how four science teachers experience the implementation of an inquiry-based curriculum. My interest in this study is born out of my own experience as a science educator. After earning my undergraduate degree and teaching license in elementary education I obtained a 7^{th} grade science position at a junior high school. My initial teaching practice relied on traditional methods for science education: lecture and confirmation activities. This contrasts with the best practice of teaching through inquiry and the use of scientific practices in the classroom. I refined my pedagogy and understanding of inquiry by completing a Masters in Science in Science Education. I changed my teaching practices and revised my school's curriculum to make it more inquiry oriented. Not long after, my school district adopted a new inquiry curriculum for my grade level. I initially struggled teaching through the curriculum as it lacked my identity that I had put into the former curriculum. All the changes I made to the old curriculum were mine. As the new curriculum was written by someone else and had lacked my input, it made me assume that it would not reflect my values and beliefs. However, as I taught the new curriculum I understood its purpose and design and fully embraced it. I wondered what this experience of adopting a new curriculum was like for other science educators.

I recruited four experienced science educators to participate in this dissertation. Each science educator participated in two in person interviews. The first interview was on their background as an educator, their beliefs in education and science, and their experiences teaching with a non-inquiry curriculum. The second interview was on their experience teaching with the new inquiry curriculum kits the district provided. A follow up e-mail was sent to 3 of the participants asking clarification questions. Each participant's interviews resulted in descriptive data that were analyzed by coding. The codes were grouped into themes and connections were made between the themes.

This chapter presents the findings as a narrative based on each co-researcher's interview transcripts. The findings will present a story of each participant's experience based on their background, their beliefs, and their experiences with the old and new curricula. The experiences will include statements and passages from the interviews to provide a richer narrative. This will help the reader come to know the participant's experience and view the phenomenon through their unique perspective.

In chapter 5 I will present my interpretation of their experiences. This will include identification of key themes and how each co-researcher's experience is part of those themes. I chose not to present their experiences thematically as is seen in some phenomenological studies. I chose to present each co-researcher's experience as a story so their experience is shared as each of them had experienced it. The section headings under each participant are not experientially thematic. Rather, the section headings serve as a guide through each of their stories.

Each of the participant's names and any identifying information, such as locations, schools, or other names mentioned in the interviews, have been replaced with pseudonyms. Participants chose their own pseudonym.

Judy

Judy is a sixth-grade science teacher. She works in the middle school that feeds into the junior high where Elizabeth, Delores, and Laura teach. Judy's 10-year career has been spent at the middle school. She started as a fifth-grade self-contained classroom teacher. She taught all subjects in fifth grade: science, math, reading, writing, and social studies. Recently, she moved up to sixth grade to become a science teacher. Her passion for teaching science has developed over her time as a fifth-grade teacher and she found she couldn't resist the call to exclusively teach science in sixth grade.

> I love science. I always have. My natural propensity is for math and science. I've always been really passionate about those subjects. I enjoyed science growing up. I would identify seventh and eighth grade in particular. I was just really challenged to think differently. I enjoyed the type of brain engagement that science class brought. Then, starting teaching: teaching math, science, reading, writing, social studies…science was always my favorite…. I loved making science lessons come to life. The more I taught it, the more I loved it.
>
> About a year and a half ago, I was really faced with that decision because I had applied for this job, my current job, as a solely science educator…. So, teaching fifth grade and teaching all of the subjects, I was just done with it. I was hoping to move on. I had disconnected with my current job [fifth grade]. The writing was on the wall, but as I developed and grew as an educator, [science] just became more and more my heart's calling.

Teaching was a career that Judy knew she wanted to go into since she was a child. She joked about how she and her friends used to play school and how her requests for birthday gifts were unusual. In discussing this she connected to teaching on a meaningful level.

> I was the only third grader who asked for an overhead projector for her birthday and got one. My entire family basement was converted into my classroom. So, teaching has always been pretty natural to me and—I feel like I was born to teach in a lot of ways. I always felt like it was my life's purpose and I always really cared about teaching in general. I love making something that's super hard be easy and graspable. I love seeing kids get excited about learning. I was really, really close with

> some of my early elementary teachers, and there was that relationship piece that somehow, I think, really shaped me. I wanted to be that person for someone else.

Judy made it clear that she was born to be a teacher. Her love of teaching science developed over time. She appreciated how science engaged students. She recognized that what science teachers did to prepare for a lesson and how they graded was inherently different than other subject areas. Teaching science connected well with her.

> I remember my first year teaching. I bought, probably, six or seven resources. I would sit, on the weekend, on the floor in my classroom, and spread out all those resources. For example, the cardiovascular system: Which one of these helps me better understand it the best? That's what I'm going to use. I loved developing lessons and materials. I enjoyed finding supplemental resources, because what we had was—meh.

This focus on developing lessons connects well with her philosophy on teaching. She believes in teaching all students and ensuring they grow. She needs her students to leave her room with more than what they came in with, be it academic or extracurricular.

> In an academic realm, I will say, I believe that every child has the right to learn more than what they came in with…. I was the one teacher who was teaching things well beyond my grade level and expecting kids to know things and defend things and learn things that were not prescribed by the district. You didn't have to do that. I feel like, academically, kids can reach a higher bar than you expect for them; especially if you have the ability to give them the tools and resources and make it engaging enough and memorable enough for them to get there.

Her beliefs regarding teaching are strongly rooted in that philosophy. She wants her students to be challenged and she wants to ensure their learning experience is a memorable one. Part of this comes from the previously mentioned experiences she had in 7^{th} and 8^{th} grade. The other part of this comes from experiences in college. She did not enjoy her teacher education experience. She felt that she wasn't given challenges and that the professors were there for their own self-interests rather than the development of their students.

> I had a terrible college experience on the whole. I hated their education program. I felt like many of the instructors were there for their own whatever. I have vague recollections of most of my experience there based on sheer repression. I do remember taking a science class. I took several science courses. The ones in science education left much to be desired. The ones in science in general I loved on an intellectual level.
>
> My science for teachers class was terrible. The stuff that we were doing was not meaningful to me. So, I felt like what we did was very prescribed. I remember very little of it. I remember doing group work for a project and other people taking credit for it. I can't draw back to profound moments in college that contributed to myself as an educator in general other than what I don't want to be.

Judy's experience in college reified her self-image of a teacher. She knew what not to do. She felt the program did not teach her how to engage students. She also felt they did not practice what they preached. She did not have the opportunity to engage in topics that were interesting within the education program. Everything was done in a strict manner. She said, "I felt like they had a responsibility to help me spread my wings and not to clip my wings and shove me in a cage." She felt limited by the program. I asked her if there was anything else she could recall and all she could add was, "I remember being cold in class."

A similar experience also occurred in an online chemistry course. She took the course after she graduated from college to improve her understanding of chemistry and to earn her teaching endorsement in science. Although there were aspects of the class she enjoyed, she found her experience to be mostly negative. This was a result of how the teacher seemed to ignore the students in the online class.

> I had a really negative experience with the class. People would post questions on the professor's [online] board. He legitimately wouldn't answer them. So I always took it upon myself to go in and answer people's question. Somebody asked something so basic about metric. It was a really quick metric question and his response was maybe you need to consider getting a chemistry tutor; contact your local high school. I was like, actually, so and so, this is a really basic question: metric milliliters are the same as cubic centimeters, which are the same as grams for water. It didn't sit well with me. I did not think it was fair that somebody could talk to students who were seeking help in that manner.

Judy was bothered that the professor was so dismissive of the student. Her own philosophy is rooted in providing every student with the opportunity to learn more than what they started with. This was an example of how that could have been easily done for this student.

Although she felt negative on how the class was run, she did enjoy the lab experiences provided by the class. The online class came with a materials kit so she could conduct experiments in her home.

> The labs were so cool. They totally made me understand the content. They were long. They took me about three hours each. I thought the questions on the lab guide were really confusing and I didn't understand the lab guide. But, I understood the lab. I understand the science. I don't understand what [the professor was] asking here. I found myself taking videos and pictures and saving the chemicals because I want to do this again.

These negative experiences, her love of challenging and helping others, and her recognition that science engages students in ways congruent with her beliefs shaped how she teaches. She knew that she needed to help all her students and that the lessons she developed must be engaging. This philosophy has been consistent over time. However, how she enacts it in her classroom has changed. Initially the way she did this was by putting on a show for her students. She wanted to bring the content to life. With the new curriculum, though, she recognized that how she taught would change.

> Academically over the past, recent, maybe year or two years, I've really stemmed more into developing a philosophy where—it's so cliché. The teacher's not driving the ship; the students are. But a little bit more of inviting the students to be more of an active participant in the process. For me, I used to say that what I loved about teaching is I put on a show. I'm an actress. I put on a show. And the more engaging the show, the better teacher I am. I would say that I've shifted.
>
> I definitely feel my philosophy has shifted towards creating situations for the kids to get where you need them to get, oftentimes without even realizing they're going there.

She shared an example of how she did this through a social studies lesson on the American Revolution. She ran her classroom strictly and gave orders to her students. Those who violated the orders received consequences. Each day, the students became more upset with how their class was treated. In response, they created a petition and expressed their frustration. Not long after, students began reading about the American Revolution and learned what she was doing. They wanted to stop her unfair treatment toward their class. So, they became invested in learning what the colonialist had done to rebel.

Her belief of needing students to be invested in a lesson is key to what Judy does in her classroom. She expressed that teaching is not merely ensuring students obtain knowledge. She wants her students to grow academically, socially, and develop their self-awareness and self-reflection.

> I will also say I super prioritize the noncurricular; some of the social piece; well beyond even just…how do we engage with others? I require my students to make cards for all of their teachers. I teach my students how to write a card. You're going to cite specific examples of—if you're thanking them for being your teacher, what did they teach you? I feel like that's a life skill that I really value for my students.
>
> Not only that, but I'm always asking my students, "What should we do in this situation?" I've struggled with co-teachers at times because the co-teachers want to say, "if you're a one, come over here; if you're a two, come over here." My philosophy is, find each other, and find a spot. Let's not make it chaotic. There were several years where I would tell my kids, "I want you to form groups. Your groups need to have six or seven people. They need to be mixed with genders, and they also need to be mixed with friend groups. If you notice that kids aren't doing that, call each other out on it. Okay, go!" Some of those little life skills, are one thing that, I think, has become very valuable to me in my teaching.

These aspects of her philosophy, she believes, can be done through her curriculum. Teaching her students how to use science in their future, teaching them how to deconstruct non-fiction text, teaching them important social skills, and teaching them to be creative can all happen through her science class.

> [Creativity is] developed in science in a way that's different than other curricular areas. You can be a creative problem solver in math. You can be a creative writer. But there is a different application level of science that develops a critical creativity that's unparalleled in other topics. I think that's really important. I also think science topics really relate in the world. So if you're ignorant in science, let's say, ignorant in why things work, then I think that leads to other ignorance.
>
> I think understanding the way the world works helps you better understand the world you live in. So I feel like there's that application piece. So now there's the obvious: careers. I think that there are so many careers that value and use science skills: innovation, ability to creatively problem solve, ability to question things. I think one of the things we learn from science, specifically science history, is not to take everything at face value and to be a critical questioner of life in general. I think that's an important skill for kids to learn.

Judy has a well-defined philosophy for teaching science. Throughout our interviews, Judy discussed how important her philosophy is to her. She may not have always done so directly, but the passion at which she spoke regarding what happens in her classroom made it clear that she holds close the values and beliefs found in her philosophy.

(Not) Going Rogue with the Old Curriculum

Judy had described her style of teaching as "putting on a show." The reason for doing this is because she wanted to bring to life the old curriculum that she taught. The old curriculum, provided by Prentice Hall, was text heavy and had few investigation opportunities for her students. She had to modify the curriculum so it was engaging for her students and so her students had opportunities to learn beyond what the curriculum provided.

> The curriculum before was book driven. I think that's where my shows came in. I was like, I don't want to teach the book. I want to put on a show. It was not—I wouldn't say it wasn't experienced based. But it was certainly not lab driven. We had a textbook. We gave tasks…. The curriculum wasn't really a kit, but we had materials. And there were, maybe, two or three special labs that we did that were loosely related to what we were studying.

> I would say—I referenced earlier, on the weekends sitting on the floor of my room. I went out and got multiple books that had to do with my curriculum. I found different ones that had readings and worksheets. We were a packet culture. So we created our packets. We used the book… but sometimes it was some photocopies from—maybe we copied three or four pages.
>
> We would include them in our packets, but then I would sit down with all these books…and I'd say, okay, I'm teaching this human body system. How am I going to do it? What am I going to do? How much time do I have to do it in? Then, how can I make it fun? So for me, I love creating. So that, to me, was exciting.

Judy put considerable time into developing her lessons. She commented on how time consuming it was. She would spend hours trying to make her lessons vibrant for her students. She would share these with other teachers in her grade level. She noticed, though, that not every teacher would use what she created. She didn't mind that, as she believed teachers have the right to choose how they teach. But, she seemed bothered that some teachers chose to stick to the book.

> I never felt guilty about changing the materials. I never felt like that was going rogue, against the district. I never felt that at all. I always felt like I could defend what it was that I was doing, and I also felt more like, why isn't everybody doing this; or—I think for me there might have been some personal reasons why I chose to do that, too. Because for me, my fulfillment in teaching was in my content delivery. So for me it wouldn't be as fun. We're going to open this book and read this book. That wasn't fun for me, day in and day out, teaching science. I wanted to have a balloon fly around the room. I wanted to have toys. I taught a lot with toys.
>
> But that has been a challenge that I've faced, because as a professional, I want to defend my colleagues, and I want to have respect, and I want to show respect for my colleagues. But it's hard to defend things when, to me, it's something that works, and I've shared it, and I would love for other people to be on board. And then they're not. I'm trying to figure out, how do I navigate that as a person?
>
> I feel like I've tried to always be pretty open with my colleagues about—happy to share. I'm happy to explain anything. Take it or leave it is fine with me. But it's always really bothered me when people have judged what I do.

Some of her colleagues worked strictly from the book. Judy couldn't do that, as it wasn't fun and engaging for her or her students. I asked her to detail what a typical lesson looked like within the old curriculum. She talked about engaging the students and gaining their interest through accessing their prior knowledge. Then, the topics would be addressed through a lab or activity tailed by a follow up discussion. But, the pacing of the lessons was problematic and left the students disengaged.

> I like to engage the kids in a way that taps into prior knowledge. I like to engage the kids in a way that helps them experience things. I think that it's essential to have some type of whole group follow up.
>
> You've got a 40-minute lab. I hope you finish. Let's make sure we're scrambling. Then, I've got a 40-minute follow up. I just didn't feel like it was a good way to meet adolescents where they were in their engagement process.

The 40-minute class period constrained Judy's lessons. The lessons, she felt, would be more productive if the students had more time to do the entire sequence in one sitting. When she asked students for feedback on the lessons, they shared that they only liked the lab days. The students disconnected the lab experiences from the other components that supported the labs and were part of the scientific process.

> I actively solicit feedback from my kids. Their feedback was matching [my feelings on the schedule]. Some kids were like, I only like the lab days. There was part of me that was like, gosh, I agree with you! But, I also needed some of that discussion and I needed some of that hey wow, based on what you're writing on your student sheets you're not getting this.

This process was frustrating for her. She wanted the students to engage in the scientific process in a meaningful way, but the schedule and pacing of the curriculum limited those opportunities. Consequently, she is meticulous in how she structures the time in her class. When that structure breaks down she must quickly assess the benefits and losses of using that time in a way that was not expected. This often came up with student questions. She wanted her students to ask questions, as it would help them connect to their learning experience. This was balanced, however, with making sure the goals of the lesson were being met.

> I feel like I want to honor my students in their questioning. I want to—when kids ask questions, pushing the concepts that beyond grade level, I want to go there for the kids that are ready. So, I've found creative ways to do that. Sometimes building in extra time in the schedule allows me to do that. Sometimes it's building in groupings. I try to make some of those groupings option so I'm not selecting who gets this chosen access to higher level concepts.
>
> I do feel like I'm intentional about things going toward the end goal. I am most successful in that when I have things mapped out pretty long term. I can really gauge where am I time-wise on some of these things. I always want to be intentional about how I'm using my time in class because every moment we do something is a moment we're not doing something else.

This process was not easy. Judy found herself in a balancing act of trying to keep the big picture focused while simultaneously addressing the finer aspects of learning.

> It's a pretty constant balancing act. That's one of the issues I had…am I going to have some subconscious motivation to focus more on [assessments] than some of my big picture ideas? Am I going to be a stickler on complete sentences for this? Did you reference the text? Did you do this? Is that what I'm supposed to focus on? So right now I feel comfortable. But who knows? Maybe two years from now, I'll look back on this moment and be like, oh my goodness, I did such a disservice. I don't know. It's the vehicle versus the road.

This balancing act was a common occurrence in the old curriculum. As the curriculum was so text heavy, Judy had to ask what the importance was in learning certain content. How much content would be necessary for the students to reach her bigger ideas and purposes in the curriculum? For example, when studying the nervous system, did the students need to learn all the different parts of the brain?

> I remember having to gauge what level was appropriate; because I think, at that time, it was up to us [teachers] to really gauge what level was appropriate for how much you're going to teach. Do I want to teach all the lobes of the brain when I cover the nervous system, or, do I not? Do I want to introduce it but not test on it? It's all those kinds of decisions.

This process was time consuming but the result, she felt, was a benefit to her students and to any other teachers who used her materials. She shared how changing the old curriculum to match her philosophy was worthwhile.

> Some people were more stick to the book, open the book, don't use a packet, don't make fun games, that kind of stuff. I felt like I had to create a freedom in that which was exciting to me. It was one of five subjects I taught. I spent the time it took to create those fun things. But it was very time consuming. I did feel like I was sort of up to my own devices to decide what it was that I was exactly teaching, how I was teaching it, how I was assessing it; and, I think, just trying to gauge within my grade level, am I in line with what other people are doing? At some point I realized I don't care if I'm in line with what other people are doing, because this is what my kids can learn; and gosh darn it, they will!

I previously quoted Judy stating that she didn't feel she was going rogue. She said this after she had talked about how she had changed the old curriculum to align with her beliefs. The reason she said this is because she wanted me to know that the changes weren't done to spite the district or other teachers. The changes she made to the old curriculum were done to make it align with her beliefs. She did this because she believes her students were capable of more than just working out of a book. She wanted to challenge them, she wanted them to grow, and she wanted them to leave with and more than what they came in with. The old curriculum didn't allow this to happen without modification. The new curriculum, however, was a better fit for her philosophy.

Curtain Call

Judy recognized a change was coming in how she would teach under the new curriculum. "I knew that we were being instructed to teach quite differently," she reflected. "I was pretty resistant to some of the changes that were suggested. But there was a lot of it that I loved." She learned of these changes when she was part of a focus group. The district was soliciting feedback from teachers in finding a curriculum kit or package that would work in each grade level. She struggled with the options that were available because the kits were too advanced for her 5th grade class.

> The SEPUP curriculum that we went with really seemed to be geared towards a very high level. I voiced concerns about it being too high and really being—I remember it being a six through eight. But teaching fifth grade, a lot of the things I found were more on the seventh or eighth grade level. My perspective was, it's easier to extend a curriculum than it is to try to break down things using resources that just don't exist. Part of that, I think, is almost my comfort level with—I feel very comfortable extending things into higher levels. I was concerned that my lower level kids—I was all of a sudden going to have to create things for them; because it was very beyond their entrance level. So how do we take these kids that are struggling with our current lower level and all of a sudden now we're trying to teach them well beyond what we used to? How's that going to happen?

A core part of Judy's philosophy is ensuring all students leave with more than what they came in with. The SEPUP curriculum made that difficult for her lower students. She saw the curriculum as a challenge for her advanced students. But, her lower students would struggle from lesson 1. She shared an example with lessons on simple machines that showed why she was worried about the curriculum option.

> There was one curriculum that had a huge component with simple machines that really tied into—it really just seemed to be at their level. I remember the text seemed to be a fifth-grade reading level. There were images. It was friendly. I liked it. I remember saying, okay, this fits with the concepts that we're teaching and concepts that make sense for force and motion. But now you want to get into this high-level math. Force equals mass times acceleration isn't that high-level. But getting into Newtons, I felt like some of the content was so mathematically higher than where our kids were. And I didn't feel like—I felt like it was moving away from things that seemed to be a logical fit and moving toward things that seemed to be less relevant.

She shared her concerns with the district. Yet, the SEPUP curriculum was adopted. Her initial skepticism of the curriculum being too advanced or not as relevant seemed to be softened as she taught the curriculum. As she taught the curriculum she recognized the benefits of teaching with SEPUP.

> In teaching that curriculum—I taught that curriculum for at least three years. I loved the topic. I loved force and motion. I loved human body. I really learned to appreciate the SEPUP curriculum. I feel like after teaching it I was able to break it down easier than I thought. But for a lot of kids I also had to extend. I felt like the extension lessons are made for students who have mastered the material and are ready for something else. How are we pretending that all the kids need the extension? That was my stand.

Part of Judy accepting the new curriculum was recognizing that she was given freedom to adjust the curriculum to meet her students' needs. She still holds that the level of the curriculum is not meant for fifth grade students but she was able to accept why the district chose SEPUP as the kit to use.

> I would still stand by the fact there are parts of it that are more geared more towards the seventh and eighth grades. I think where I found a lot of freedom was understanding that I had the academic freedom to modify those in a way that worked for me. Or, I had the academic freedom to skip certain lessons that were not as in line with what my kids—where they were in general. So ultimately I think in a lot of ways I was right. But I think in a lot of ways the district was more right.

She felt the district was right in regards to selecting a curriculum that embraced inquiry learning. The new curriculum would allow students to be inquiry learners whereas the previous curriculum did not naturally provide that opportunity.

> I think they [SEPUP] wanted the students to really learn how to be an investigator, and one of the ways they did that was by really helping them understand how to be an active note taker. I think it was, let's help you formulate questions so that when we start to really learn about this, you're seeking the answers to your own questions and tying your experience with the content, with your own curiosity but also just having multiple vantage points versus the text orienting everything. The old curriculum the students read for information. They were information sponges. So their purpose was, let's read the text. But now it was the lab experience orienting things.

Judy's comment that the students were now active note takers could be misconstrued as simply processing a text. What she meant, though, was the students were like scientists in that they were documenting their experiences as rooted within a lab or investigation. She noted how the students responded well to this new style of learning.

> I do think that the kids are more excited about science on the whole. It's not as much—well, some kids are excited about science and some kids just read a textbook. The kids get really excited about what to do. My biggest thing I have to harp on with them for is, you can't go and tell all your friends what you just did in science class. They have to wait, too. Because after class it's like hot gossip. They want to run and tell—oh my gosh! Guess what happened in science today? I love that, but spoiler alert. I do think it helps the kids with learning how to be thinkers. I think it helps them be those problem finders and problem solvers. I feel like they are more equipped to handle some of the rigorous demands that the curriculum offers, and it is extremely rigorous.
>
> I also think a strength is it really helps kids who may struggle with reading because it's not focused on the reading. It's focused on, yes, there's reading: so that's still a skill we're working on. But it's focused on the experience. So now they're able to tie in a variety of learning modalities within the same context. So that's a strength.

She also found that the skills the students were learning were transferrable between the grade level subjects. She also felt the curriculum increased collaboration between the students, a skill that was not provided in the old curriculum.

> Some of those skills are transferrable—claim/evidence/analysis. We didn't use that with our old curriculum. In all fairness, maybe it could have worked there, too, and we just didn't use it. But providing the claim using evidence to support your claim, and then being able to scientifically analyze and reason through your claim—I think that skill has opened up a lot of doors for the kids. I think it's transferrable to ELA. I used it as a reading and writing teacher all the time. It's transferrable in social studies. It's just a good learning skill.
>
> I also find significantly more collaboration. So I will say I think that's a life skill that the kids really learn to develop, especially in science.

This new way of learning for the students also connects back to the point initially mentioned in this section: how she taught would be changing. With the lab experience, and not the text, as the focus of the curriculum, she recognized and accepted her role as the teacher changing.

> I feel like I was already good at asking my kids critical questions. But those critical questions were asked in my class in a whole class setting. Then we'd explore some ideas; but right away, I would correct all their misconceptions and show a visual, and we would get the right answer. I feel like it switched from a whole-class to more of a group investigation.

> So I think my role as a teacher was knowing what I was looking for and what I wanted the kids to get. And also anticipating some of their barriers to entry for those. So I might walk around and be like, hmm, why do you think this is happening? Or—really my role as a teacher also shifted because I became more of a questioner. I also became a little bit more of—I wasn't quick to give answers. It was more like, huh, I was wondering that, too. Why don't you guys see what you can figure out? I felt like it was more engaging in that learning process with them versus jump on my party train.
>
> I think it was a little bit more of me moving around the room and engaging in discussion, and then occasionally being like, hey, this is something we would all benefit from. Let's all join in that discussion. Okay, we shared some ideas. How do you think we could investigate that? Good. Now you all go try that and let's come back together and see what we found. It became a lot more investigatory. It also become more rigorous and it wasn't me prescribing to the kids this is what you're learning and how you're learning it. It was like—I know what we're learning. I know what we're going to use to get there. But there's a lot more openness within the pathways.

Judy appreciated the openness in the curriculum as it allowed her to be more flexible in structuring the learning experiences for her students. This meant she could more easily implement her philosophy in her classroom. Her students also recognized how their role changed.

> The kids don't look to me as the keeper of answers. They're less focused on me and my opinion. I think the kids have the ability to be more critical thinkers themselves, because they're not just sitting there waiting for me to tell them what they did right or wrong. We never do that. Just like in their learning process: they're not just sitting there waiting.

The school district provided professional development for Judy to familiarize her with SEPUP and to learn how to teach the new curriculum. She found the training to be beneficial but there were aspects of it that did not sit well with her.

> I felt like the SEPUP people were training us on the SEPUP way. There were things they were saying that we should be doing that I felt weren't in line with our district philosophy. So there were things that I was like, wait a minute. What? Why would we do that? Or things that I was like I would never do that. But I did feel they walked us through it assuming that we had very little background knowledge.

> What I think was the downfall in the training was the message that was given. This is the way you go through it. There really didn't seem to be a lot of ifs, ands, or buts about it. There was never a message of do what's best for your kids. So I felt like that really created an issue for us moving forward because there were things that weren't working for our kids; and it wasn't working in our timeline.

Receiving the message that the teachers needed to stick to the SEPUP method did not sit well with Judy. The ability to modify the curriculum is a must as Judy believes that learning must be accessible for all students. And, not surprisingly, that's exactly what Judy did.

> I found the inquiry model to be present in the SEPUP curriculum, but sometimes in a way that was hard for fifth graders. An example of that is the chicken wing dissection. They wanted the kids to do the chicken wing dissection prior to learning anything about the skeletal system, muscular system, any of it. So it was that, let's dig in and find stuff. Then later, we can be like, do you remember that squishy thing? That was a muscle. But the issue was, the kids, as learners, weren't oriented in that way. So I did go off script, where I gave them some background basics. It wasn't encouraged. It didn't really follow the inquiry model, admittedly. But I gave them some background basics so that, when they were doing their dissection, they were like, I found a tendon! Because I know what that is. Wait a minute: would this be a ball and socket joint? They could use the vernacular. They could look for things when they knew what they were looking for.

Without this modification, Judy felt the students were missing key takeaways from the curriculum. She shared this observation through a discussion on how SEPUP asked students to analyze their work. She liked how the analysis questions covered a variety of learning levels but found students still struggled with them.

> I like the analysis questions. I liked that there were just a few of them. I felt like they were fairly leveled. There were some of them that were just comprehension level, some of them that were more and deeper connections. I will say that I did find it to be hard for some of the kids. Part of the reason why I think it was hard is because they weren't thinking on all those levels. So they might have gotten the first analysis question, but third and fourth ones—they were so far off.

Judy taught with SEPUP in fifth grade. She later transitioned to teaching sixth grade science, which used the STC Secondary curriculum. Judy did not receive formal training with the STC curriculum like she did with SEPUP. This is because the curriculum had already been introduced two years prior. She, instead, received training from the content level specialist for her grade. Although she felt the training lacked in certain areas, her confidence of being a good science teacher supported her as she went through the sixth grade inquiry kits.

> We mostly went through the binder, and that was helpful to a certain extent. But it's also overwhelming. We had, I think, a half day. It's hard to train somebody in that short amount of time, especially when that's not your consistent job. I feel like there were several things that were really left out of that training. It wasn't until significantly later in the year that we discovered that some of those things were left out. At that point I had already established routines and my mind around the way things were.
>
> In spite of that, I will say I love science, and I love teaching science. And, I feel like I'm an equipped science teacher. So, to a certain extent, even though I felt my formal training left much to be desired, I was able to still figure it out. I know how to teach. I knew how to use lab materials in an effective way with students. And, I knew how to change things up so that they were really analyzing things and getting to what I needed to get at.

Judy found differences in how STC was structured compared to SEPUP. She commented on how she felt STC was not as inquiry oriented as SEPUP because STC lacked a central or guiding question for each lesson. Instead, STC provided objectives of what students would be doing in each lessons.

> Sure. I will say that the format was not quite as conducive to inquiry learning as I would have preferred. So instead of having that big question that we're trying to answer, and it's right there in your textbook, the textbook is a lab manual. So it's, here are your lab procedures. There are some images. I found that I had to be the one who be like, here's this question; can we answer it. In my professional development within my current curriculum, I haven't gone through and aligned every lesson where I'm posting, here's the subjective question that we're answering today. It is something that I think should be done. I know that there are objectives in the manual, but we don't do everything in the manual; and the objectives don't always line up with all the standards. So I think that's a work in progress.
>
> The format, I think, for the kids, was, your lab procedure is in a book. You have a student sheet, separate. I liked that that student sheet was provided, versus sitting

> down and copying a bunch of stuff from the board. But I liked that. But I think it was hard for the kids to have that transference: I'm doing this here, and I'm doing this here. It just seemed like a lot for some of them to juggle. I found more success when I created my own student sheets that combined the procedures and certain things throughout: Take a picture of this; insert it here. I still kept, actually, the format from the SEPUP curriculum; because the STC—I forget what it calls it, but it doesn't use the term, analysis questions.

Judy felt the structure of SEPUP was better for inquiry than STC. Yet, the student materials for STC, overall, were better than SEPUP for her students. She ended up taking the best aspects of SEPUP (e.g. the guiding and analysis questions) and combining it with the best aspects of STC (e.g. the general flow of each lesson and focusing on data).

> What I will say is, the lessons are broken down into – there's usually getting started; or the first lesson in it is extremely exploratory. I appreciate that about it, especially in the chemistry curriculum. It's very much, we're going to spark a lot of questions; and then we're going to spend the next three and a half weeks going through activities where you go, oh, this is just like when we did that. Oh, that's why it's happening. I like that format. So it does go through a progression like that, and I like it.
>
> I think one of the things with STC that's – well, I guess this was in SEPUP. I just find that the kids really, on a consistent basis, are collecting and recording data. I feel like the STC curriculum does a better job of using the actual data. So your questions are relevant to the data, versus, I felt like with SEPUP, the questions were more relevant to what you learned when you analyzed the data. So you had to take the data, analyze it, get an understanding of what the data represented; and then you used that to answer the questions; versus – I think the STC curriculum ties back directly into the data. What was the density of water? Well, you've got to look back at your chart and read it, versus maybe getting into, how did the density of water change whether something was sinking or floating.

Judy is now teaching the STC curriculum for her second year and, with some modifications, feels it is a great fit for her and her students. In general, she feels that the new inquiry curricula are a better fit for her teaching philosophy.

> Well, I will say, I want my kids to be inspired with science. I want them to be excited about science; not from a comparative standpoint, but I want them to learn more than they knew when they came in; and I want them to learn to be thinkers. The inquiry based model does that so much more, because while I felt like my kids were very entertained in the past, they were learning because I taught it to them.

> Now I feel they're learning because they're figuring things out. They're able to put the puzzle together. I might provide some of the pieces. I make them find a few more. But then they put it together, and then we look at the picture and talk about that as a group. If there were any pieces missing for certain kids, we can help fill those in. I really like that. I think it fits with the way that I want kids to learn. It fits with that short-term cost/long-term benefit. I want them to learn how to be a learner. I think it helps them learn how to think and question and self-regulate. It helps with their awareness, that they need to have an understanding of the correct procedures for things. I think it helps them tie content to their memories and experiences.
>
> I've always been a visual teacher. So I feel like, in a lot of ways, this is just less demonstration and more of the kids actually doing it; because I have enough supplies for them to all do it. Where I think I still struggle as an educator is, they still don't always get it; and that's hard, because it's like, ugh, you just saw this. How do you not get it? But I also experienced that in the old curriculum. So maybe that's just teaching.

I asked Judy to reflect on this some more. I wanted to know if she felt that her understanding of the concept and value of inquiry has changed over time. Did she have more knowledge of what inquiry is now that she has taught with inquiry kits? Did she have an appreciation for what inquiry offers as compared to before she taught with the kit? She felt that she did.

> It definitely has, especially my acceptance. I think what I still sort of struggle with is now just a challenge that I'm working to overcome versus a barrier to entry, like it was before: Why would I spend all this time for them to not get it? Why don't I just tell them? They'll get it then. Then I know they get it. I think that was more my philosophy; and now I value the process so much more. I didn't value the process before, quite frankly. I was sad to see my show have a finale. But now, in a lot of ways, it's still there; it's just not what we spend the whole period on. I can still give visuals and mnemonics, but to things they've come up with, and they've discovered.
>
> Recently I asked my students – just the last open ended, no-points question on a quiz – do you feel like you understand the expectations; do you feel supported as a learner; is there anything you want me to know about your learning style; just a variety of different questions. Here are some thoughts. You can respond to all of them, none of them. Do you think your group is working well? Just that moment of check-in. There were several kids who actually wrote I learn better when I'm doing a lab because I can see what I'm doing or something along those lines. They literally made that connection.

> I found that to be some evidence to support my claim, philosophy – an inquiry model. I was like, you know what, I know I'm struggling because I think they're not getting it; but that doesn't mean I need to switch over to direct instruction and make sure they get it. It just means I need to guide them a little bit differently. I think that was one of my takeaways. I didn't expect so many kids to have that reflection: I love it when we do labs, because I learn more. It was cute. It was really cute to see them reflective like that. I'm like, oh, yay. You do know you're learning.

As Judy becomes more comfortable with inquiry, she begins to question how to assess the students. Does she focus on the content? Does she focus on the skills? Does she allow students to use her notes?

> What I'm trying to think through is, I some of that also true for science, where—is it less about the content? Is it more about the procedure and that process and the scientific awareness? If so, how are our assessments reflecting that? So then, should we be testing on the content still or no? I think that also gets into some of the questions of, should the kids be using their notes or not. I'm a fan of using their notes if their notes aren't giving them the answers. If their notes are giving them information that they still need to process and analyze to figure things out, great! If you can look in your notes and find the answer, then what are we doing here? What are we testing you on, your ability to find an answer?

Assessment is a focus for Judy now. She wants the assessments to focus on aspects of science for the students. She wants to see them use the skills they have learned through their investigations. Consequently, she now questions the purpose of having students memorize content. She would rather have students use the content to address the scientific practices and respond to deeper thinking questions.

Summary of Judy's Findings

Judy's teaching background has offered a unique look at how she has experienced the implementation of the new inquiry-based science kits. Judy made it clear she is passionate about learning and teaching science. She feels it fits well with her philosophy of making learning engaging, exciting, meaningful, and challenging for her students. The science curriculum is more than just learning a body of knowledge and skills. Science curriculum is a way to teach other values: collaboration, critical thinking, problem finding and solving, and self-reflection to name a few.

Her experience in adopting the new fifth grade science curriculum caused Judy to reflect on how she taught science. It was her responsibility in the old curriculum to make learning come to life; she wanted to make science fun. She did this by putting on a show, bringing in toys for students to interact with, and by ditching the textbook and creating her own curriculum materials so science was more engaging than simply reading out of a textbook. In the new curriculum, she realized her role was to now guide the students through the learning experience as the experience was inherently fun. She accepted this change without problem. She felt the new curriculum was not a perfect fit for her or her students. So, as she had done with the old curriculum, she changed it to make it reflect her philosophy of teaching and learning. She added content where she felt it was lacking. She rearranged some lesson sequences by providing students with background knowledge so explorations would make more sense to them. She also modified questions so students could grow at various levels. In moving to sixth grade, she found that the STC curriculum lacked certain aspects that she liked in the fifth grade's SEPUP curriculum. Again, she modified it to make it fit her philosophy of teaching science. She added central questions to lessons so the students were working toward a bigger idea. Although she liked the student materials, she found the student book was too much of a lab manual; it did not serve as a learning guide as much as it did a list of tasks to complete. So, she combined what she liked of the SEPUP and STC kits to align the kits to how she believed science should be taught.

Judy made it clear through her interviews that reflection is an important part of her practice. Her reflection has helped her improve as a science educator and provide what she believes is the best learning environment for her students.

Elizabeth

Elizabeth is a seventh-grade science teacher in a suburban school district. She didn't always know that she wanted to become a teacher. Her initial passion was dance. However, the reality of being a professional dancer made her question if this would be a possible future career.

> [Dancing] was grueling so that kinda evolved into I won't be a professional dancer; maybe I'll be a dance teacher. When I was in dance in high school I used to teach children dance so I would teach dance classes. I knew that I liked working with kids as well. So that kind of evolved into "maybe I'll be a dance teacher." And then I realized dance teachers don't make any money at all! [Laughs]. So I made the decision in college to keep dance as a hobby and then teaching kind of felt like the natural next step for me.

How she came to teach science seemed almost accidental. She had a passion for science without realizing it. It wasn't until she applied for her teaching license and was granted a science endorsement that she recognized her love for teaching the discipline. Teaching science felt like such a natural fit for her.

> When they checked my transcripts I had enough science courses to pursue that as an endorsement. And it was kinda funny because I felt I had a passion for science without even realizing it. Because I took as many science courses as I could in college…just because I liked them. And so it just almost seemed like a natural thing. Like, I knew when they checked my transcript it would probably be that. And then, it was. It was I guess I'll be a science teacher! Of course I would teach science if I had to pick! I loved those in college and in school as well and growing up.

I asked where this love of science might have come from. She said it was simply a part of her experience from growing up.

> I was always pretty curious. I always loved living things. In school I never had any problems with any of my science classes. I always thought they were fun and exciting. Everyone would complain about how hard they were. "Oh God, chemistry!" they'd say. And I would be like, "I love this! This is cool!" You know? So, I always just really enjoyed it in middle school and in high school, which is why I continued to take it in college. I wouldn't say it was easy for me. But, I didn't mind studying for it. I didn't mind working harder to take higher-level courses.

Her college career included science courses in chemistry, geology, biology, and a course in astronomy. She went beyond the minimum requirements for science. When there were additional choices for classes, she would take a science course.

She has taught for 17 years but not all of them have been in science nor have they been at the same school. She has made her school district home for her entire teaching career. She began in her school district as a paraprofessional before becoming a full time teacher. Her first teaching assignment was in the district's middle school.

> So at the time I was at the middle school teaching math and science, which I loved. I was there for 12 years. But, after teaching math and science for 12 years, I knew that science was really what I enjoyed most about the job. And then, our junior high is 7th and 8th grade and the job openings never really opened for science there. So, there was one year when one was open and I came. I made a dash for it. It all worked out well and I've been there ever since. And now I get to teach science all day long, which is amazing!

In both interviews, Elizabeth's passion for science was made very clear. How she talked about the subject and how she teaches science just made it so transparent that science is what she loves. This will become more apparent in Elizabeth's philosophy of teaching science and her experiences with the old and new curricula.

Fun: Evolution in Action

A key word that appeared throughout Elizabeth's experiences was *fun*. When I initially asked her to describe her philosophy of teaching she honed in on that one term.

> My general philosophy is that learning can be fun. I think that's the basic, bottom line. Um, my favorite teachers growing up were the ones personable, happy, and laughing and having fun with us. Like, you could tell they wanted to be there. And, I like having that type of relationship with the middle school students that I work with. So I think my number one philosophy is how can I motivate them in a way to show them that even though we are here every day, all day long, this is fun! And, I think for kids, for the age we work with in middle school, it, that's half the battle is motivating them. So, if you can show them that it's, it's fun, that it's natural, and that it's a good thing...so I really am, really kinda try to make sure that each day is something fun, which can be stressful, which maybe is a topic for another day.

Part of why Elizabeth believes this is because of what she's observed within her district. Parents comment that school loses its fun towards the end of the elementary years.

> A lot of parents will be like, "Oh, you know it's fourth grade: it's not fun anymore." They'll make comments like that. It's like a dagger through my heart as a seventh-grade teacher. You know? You don't want to have to fight that battle. So, I think it's something as a teacher I have always wanted my philosophy for myself, or my goal for myself, to always not let that, not let it become that. My goal, my mission, I guess, to say that "No! Fun doesn't end it fourth grade!" It doesn't have to end!

Elizabeth feels she is successful in implementing her philosophy in her classroom. Parents and students frequently share that they enjoy her science class because it is fun. Receiving this feedback fuels her passion for teaching science.

> I feel like I wouldn't continue doing what I'm doing if I didn't. Like I definitely, you know, it's definitely one of the rewards of teaching is to be able to know that kids enjoy being in your classroom. So, that sort of feedback really keeps me going and keeps me motivated to keep doing what I'm doing.

How she makes her class fun has changed over time. In the prior, traditional science curriculum, making learning fun was about learning without having to always lecture and involving physical movement. This contrasts with the new inquiry-based curriculum, which naturally lends itself to being fun due to its investigatory and inquiry style of learning.

> I don't think I ever at the time, I thought that, I can't make this fun. I still made it fun, but I didn't know back then what I know now. Now I look back and I made it fun. But now it's more naturally fun. Like, this is fun for the learning; inquiry is fun for the love of learning. Let's take the content and make a fun game or get them up and moving, or you know, I was applying some kind of game or activity to make it fun.

> Whereas now I feel like running inquiries is fun for our kids. They get so excited when they come in on inquiry days. There are no bells and whistles, or it's a fun game and there is a challenge and there is a competition; there is none of that. It's we're going to have a lab: "Yay!" Like, [laughs], you know? It's like it's naturally fun now. Whereas before it was hard to work to make it fun.

Here Elizabeth makes clear how the term *fun* has evolved over time. Much as species evolve over time due to changes in their environment, so too does the meaning of *fun* change based on the curriculum. The new curriculum is fun in a different way than the old curriculum. In the old curriculum, fun meant playing a game or moving around the room. In contrast, fun in the new curriculum is due to their natural curiosity being piqued through inquiry activities.

Throughout our conversations the term *fun* was often used in conjunction with the phrase *hands on*. I asked Elizabeth to clarify if hands-on is the same as inquiry. She clarified that they are different. She said there are times where hands-on means "doing mindless tasks." Inquiry, though, is a much deeper experience that engages students in a different way.

> No, I mean inquiry is minds on, for sure. So I feel like, you know, sometimes inquiry can be a question that you're just thinking about or, you know, brainstorming about or answering. It doesn't necessarily mean you're doing a hands-on lab or activity to get to the answer. I think when you're hands-on, though, it's just like a double bonus, because you're hands-on and minds-on, like I think that, you know, what is that, like if you, like that tactile, when you're actually physically doing something, it's in your memory for longer. And I think as far as motivating students of all ages, the hands-on is a big piece of it.
>
> But certainly an inquiry mindset is not necessarily always hands-on. It's just that you're able to sort of open up your mind to think about something on a deeper level or two. Think about multiple perspectives of something or, you know, be able to look at an observation and draw a conclusion from it, doesn't have to be hands-on. It's more fun when it is.

I chose to discuss her philosophy of fun before going into the next section as it frames what she believes is important in teaching and learning science. The antithesis of fun, for Elizabeth, is when the curriculum's focus is on content. This isn't to say she doesn't value the content or have an appreciation for it. She just doesn't believe that science should be a transmission of content from teacher, or textbook, to student. The content should be a way through which students learn about science and learn how they are part of the world.

The Role of Content

Elizabeth believes the purpose of science goes well beyond just knowing the discipline as a body of knowledge. She reflected on this when I asked her how she evaluates her students' work. She expressed her struggle with this. She wants to grade her students on more than just content. She wants to grade them on their process. But this is not an easy task to do.

> Well, when I try to evaluate all, labs especially, I try to evaluate them on a variety of things. So, if the content is off a little, it's not going to kill your grade, so to speak. If you followed the right process, or if you have some rational explanation for why your answer is the way it is. A lot of times I try to look for why their answer is off, them being able to explain why their answer is off. They usually do know. I'm thinking through it. They usually can see the whole class data and they know if their data is not fitting in there. I definitely try not to [just grade on the content]. There are definitely some assignments that are content based that I'm grading on if they know the content. Um, but a lot of what we do in science that…most of what we do in science is really more about the process. And the content kind of falls in place from there. Their grade is certainly not only based on content.

Part of her aversion to grading just on content comes from her own experiences in not knowing the content. This isn't to say she is not knowledgeable in certain content areas of science. Rather, when she is learning a new topic she needs to research that topic and learn the content. Similarly, her students are likely experiencing content for the first time.

> The content, it depends [laughs] on what it is. I definitely do struggle, I think, or I beat myself up a little bit about not, if I don't know something. If a kid asks me a question I don't know, I'll beat myself up about that and later tell myself, "there's no

> way you're gonna know everything and answer every question scientists have ever asked."

This experience of not always knowing the content is built into how she evaluates her students' work. Her students find this a bit frustrating as they are used to having a right or wrong answer. In science, however, your investigations determine the answer. The investigations, however, don't always lead to a simple outcome.

> They struggle with when there is no black or white answer. They want there to be an answer. They want there to be a right answer. If the data doesn't match up, or if there are outliers…they look at you and ask, "Well, what is the right answer?" You're like, I don't know.

She discussed this further in an investigation she has her students complete to demonstrate the process of collecting data on a living organism. The students are asked to use their microscopes to determine the pulse rate of a worm. Each time the worm's blood vessel constricts the students record that as 1 pulse. The students struggle with this as there is no right answer. The pulse rate can vary based on the state of the worm, if the worm was moving, or where on the worm the student collected the data.

> I recall going back to the handbook and being like, "what is the right answer?" I was so frustrated with…even then the right answer is like a huge range. Trying to explain that to the kids… In math there is usually a right answer. In science there might be a range of answers or a trend or something. They have trouble with that. Trying to teach them, you know, what they've learned or what they think they've learned and where that sort of falls in to where is that a theory, is this true, has this been tested? They really have a hard time with that gray area.

It becomes apparent here that Elizabeth's experience in adopting the new curriculum was not straight-forward. Although her beliefs about science education are aligned with best practice, Elizabeth notes the same frustration in getting used to there not being a right answer.

This agitation in the new curriculum not always providing an answer is rooted in how the old curriculum was structured. The old curriculum was content focused. When I asked Elizabeth to tell me what she taught in the old curriculum she listed topics over processes.

> We taught a lot of rocks and minerals. We spent a lot of time on minerals. We studied different types of rocks and the rock cycle and the geologic timeline. And then in biology we did some cells, we did the kingdoms…. Sorry, I'm trying to remember. So we kind of worked through each kingdom and within that we had labs and observations, microscope work, and then dissection at the end.

Elizabeth mentioned rocks minerals a few times in the interview. It was clear that this was not a topic she enjoyed teaching, as it was not aligned with her beliefs in teaching science. So, I asked Elizabeth to talk more about the purpose of studying rocks and minerals.

> Rocks and minerals is one little bullet point on the NGSS standards within, you know, a topic umbrella. And for us it was like an entire semester. I guess that is a full circle moment back to learning should be fun. So, if we're studying minerals for three weeks eventually the kids are going to be like, "Really? Really!?" You know, we would try to make it fun. We would do mystery minerals and other stuff. Essentially it was the same topic for a really long time. And the kids were like, "Hmm, okay." Whereas now, I feel it's like the opposite. We have so much. It's probably better. I feel like even my old curriculum at the middle school everything was a lot more content focused versus process focused. It was more about content in the past.

Whenever she talked about the old curriculum she always compared it to the new curriculum. For example, she brought up the role of the textbook in the old curriculum. The textbook she described as being "dated many, many moon ago." Despite its datedness the textbook served as the foundation, or starting point, for learning.

> A lot of the curriculum materials we got before was like a textbook. And, that was kind of your starting point. You know? And every once in a while, there would be a little lab in the textbook that would be kind of dumb. [Laughs] Sorry! And then we would go out and like research and try to find activities and labs that went along with, or kind of helped or verified, that went along with what we were saying.

The “dumb” activities, she noted, were not inquiry based. They existed to confirm what she or the text had told the students.

> Most of them were quick, almost even just little demos. So, a quick little demo that re-illustrated air pressure that the kids have seen or done before. And, has like one outcome: the one that it is supposed to be. Like one page of the book…try this…why did it happen? It was something you could in 5 or 10 minutes. Whereas I feel like, you know, the kids are more excited about a lab that you can kind of go through and test numerous times and have different outcomes for.

This format of learning through memorization of content and verification through demonstration goes against what Elizabeth believes is important for her students to learn in her science class. The old curriculum didn’t allow students to have a sense of wonder or discovery.

> So now I’m just going to watch it happen. So there is no wonder or hypothesis or prediction…. A lot of times It was one of those before you even got the materials out, the kids were like “Oh, this is what is going to happen to the balloon.” It was supposed to be a fun thing that you did. But it ended up just being this quick demo of what they already knew was going to happen. Not very fun.

Between the “dumb” activities and the centralized role of content, Elizabeth described the old curriculum as “heavy content; kind of, you know, snooze fest.” This is why, she noted many times, the content is something she doesn’t make a focus in the new curriculum as it is always readily available. That is, if she or a student needs to know some content, it can easily be obtained through a resource. She elaborated on this when she reflected on the first time she taught the old curriculum and had to learn a new set of content.

> I definitely have a…even myself as a learner I have…a hard time remembering. Like, I can’t memorize all that stuff. I don’t have that type of brain. I think science is hard in that way.
>
> In both the middle school and the junior high school, I definitely took some time to warm up to the curriculum. I think, you know, having to remind myself what I was teaching and having to kind of freshen up a little bit on the knowledge of those

> content areas myself. But I think I did, you know?... But at first it was definitely uncomfortable because I wasn't as familiar with the topics… I had been teaching other topics for 12 years and I was like, oh, okay, now I have to remember what it's like to teach cells.

Even though she had to learn new content, the skills she was trying to teach were still the focus of her classroom. It wasn't something she had realized until a colleague had pointed it out to her. It was something she reflected upon with me when I asked her if she ever felt worried when having to learn new content to teach the students. She said she didn't worry.

> I agree. I feel like I also have a solid…I'm only saying this because a [paraprofessional] once told me and I never thought about it. But when I came to the junior high I had been teaching for like twelve years. One parapro was like, "you really understand, sort of, just, how to teach kids." You know? Like, regardless of the topic. I never thought about that. I was actually very humbled by that. I never really thought that, oh, she basically said you have a solid understanding of instructional, what works for the kids, and how to take a concept and make it work. So, I feel like that also helps sort of boost me, especially in a new job, in a new curriculum at that time. I thought: well, if I know how to teach kids, I know how to figure this out. If I know how to teach science and I know how to teach kids, I can figure this out.

This is one of Elizabeth's strengths: she knows science as a practice and she knows how to teach science as a practice. She knows that the content is a way to address larger issues and bigger ideas. She knows that content doesn't need to be memorized but it needs to be applied to analyzing and problem solving. She sees a bigger purpose in teaching the students science.

> 'Cause there are some things that you teach that is not going to serve them any purpose in life to memorize this for a test for once. Like, I'm trying to each more of the skills than the actual itty, bitty pieces of content.

Science: Learning for a Greater Purpose

In the previous section it becomes clear that content does not play a central role in Elizabeth's classroom. Her decentralizing the content is so that scientific processes can be in the spotlight; the content, obtained through discovery, becomes a means through which the processes can be learned. This is for an important reason. She wants her students to experience science such that they recognize their responsibility in the world.

> I feel like we have a responsibility to respect our earth. And, I don't think a lot of kids don't take the time, a lot of middle school kids, don't take the time to stop and think "wow." I really try, in our geology until, really try to start off with this video; I try to theme the unit with I heart earth. I definitely am trying to help them, like, have a bigger appreciation for the system that we live in. And how amazing it is that all of these parts work together so that you're able to live here and do the things you do every day and how much of that is science. That how much of every part of your day, whether it be the technology you're using or the weather, or the trip you're going on, to going skiing or whatever. Like, every single thing is somehow related to the system at work on our planet. And what sort of a big idea that is. And I think that, you know, I try to do this I heart earth thing. 'Cause I feel like we have a responsibility as humans on this planet to respect and honor that. And I kind of try and help my kids see that.

Part of how Elizabeth does this is by instilling a sense of wonder and curiosity in her students. She wants to connect them to the Earth and have them appreciate the amazing things that are occurring within it. Earlier I shared how Elizabeth struggled with teaching rocks and minerals. It was focused on so many details that were irrelevant to the students' lives. She adjusted the old curriculum to make the unit more meaningful for the students.

> My goal was to help them see these rocks we had been looking at in class every single day were from larger rock formations that shape our planet. And our planet looks to be this way for a certain reason. And in that point our old curriculum did not have a lot of plate tectonics in it. So, I introduced a little bit of that as well, which I think was not on the curriculum at that time. But, through that project I introduced more of that. So I definitely included more process and real life connections. I felt it was very this-is-a-mountain-it's-made-of-igneous-rock. But for them I wanted it to be something that connected to them. This is Mount Fuji. It was formed this way over millions of years! Just opening their eyes to how cool our planet is. Kinda back to that thing. I still try to do that with pictures that I put up every day. Just to help them appreciate that mountain you skied on over winter break has been built by a process over hundreds of thousands of years.

By giving her students an appreciation for the natural beauty and the powerful processes occurring around them, she hopes that they will leave her class with a sense of wonder. She wants them to appreciate what is happening in the world. And, in doing so, she hopes that her students become more curious about the world.

> I feel like giving them the permission through their whole entire life to, um, "oh that's not true anymore," or "I want to look into that." You know, even as an adult follow that same process, even if it's not about science. It's questioning things and finding any answer that works for them and not just doing what other people tell you because that's what you said.

Presenting science as content goes against her belief of having her students become curious of their world. What is there to be curious about when someone else has already found the answer? Why see the world as a place full of undiscovered ideas when you learn science as a body of pre-existing facts? This is why she focuses on the practices of science. These practices lead students to become curious about the world.

> Well, I think that they, you, uh, throughout your whole life, even as an adult, you can question things and wonder about things and learn about things. It's just that, sort of, there's not just one right answer. There's not an end to what you can learn. So, I think that even big picture, teaching science is a feeling you want to give kids that you can always learn more. You can always learn…things change. You can evolve, you can learn something differently. Or maybe something you believed is true for your whole childhood is all of a sudden not true.

Elizabeth felt constrained by the old curriculum. She wasn't easily able to instill this sense of wonder in her students because the curriculum was so content focused. This was not the case with the new curriculum, however. She remembered how excited she was when she received her materials for the new curriculum. Each unit came with several large bins full of the lesson materials.

> I do feel lucky that we have what we do. Like, the amount of materials that came with our new curriculum in those boxes. I made the joke that it was like Christmas while unpacking those. Like, "are you kidding me? All this stuff for us!?"

> Oh, that was an exciting day. I can remember unpacking it all and being very exciting for all the new materials. Yeah, no, I mean the kits were great. I feel like I would have never known that I needed all those materials, so it was all very well spelled out like for this lab you needed these materials and, you know, it was all in there. Which was

> really exciting. And some of it was new and different stuff that I had never worked with before, so that was exciting. But there's a lot of stuff.

It was exciting for her because those materials meant her students would be doing science. Her mind predicted all the engaging activities and investigations she and her students would be doing throughout the year.

> I'm always excited for like new labs, new inquiries, and I liked that, you know, a lot of the stuff we were talking about definitely, you know, had more live organisms and things I had never done before lab-wise that I was pretty excited about.
>
> But I think that was exciting also in the fact that it was true that we were really going to start doing more inquiry, like we had more stuff, which meant we were going to be doing more hands-on, you know, lessons. But with hands-on lessons comes an enormous amount of material. I mean I think that's, you know, the kits that we got were great, but we're also very lucky that our district's able to provide us with those types of resources. But yeah, they were, it was like Christmas day. I just kept opening boxes and there was just more and more cool stuff.

Although she was excited for what was coming with the new curriculum, she recognized that her role as an educator was going to change. Although she had made the old curriculum more inquiry oriented, the new curriculum was built upon an inquiry framework. This meant that she had to transfer more of the control of learning to the students.

> Yeah, it was exciting. It was a little like nerve-racking at first, because you had to really accept the idea that you were going to let the kids have more of a say in some things and that sometimes things weren't going to go right and you were just going to have to go with the flow and figure it out. So you kind of had to let go of some of that control that you may have had in the past.
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> So that was a little like, you know, like exciting but nervous exciting. But I do remember thinking also that I felt like a lot of the lessons could even be more inquiry. Like in with my colleagues, we kind of took some of them and even made them more student led or more student directed the first time we ran them just to see what would happen.

Transferring this control was not something she or her colleagues were averse to. As she stated, she and her colleagues looked for ways to give more control of the learning to the students. She spoke at length about how the students gained so much responsibility for the learning with the new curriculum. The students created the learning experience and she believed that gave the students so much ownership of their education.

> It's a lot more hands on, I think. A lot more ownership of sort of, you know, the responsibilities of, you know, sometimes they even set up their own procedures but even when they're following a procedure, you know, definitely, definitely a lot of ownership on them that they need to be following it and you know, doing it correctly or, you know, the risk of messing it up kind of a thing is real. I definitely think it's just more in their hands. Their learning is more in their hands, so like even the observations and things that they write down, they have to be able to sort of connect their own observations to a scientific concept later, vs. a prescribed set of things that their teacher said.
>
> You know, how does this relate? They all have their own drawings, their own, you know, notes that they jotted in the margin, or their own observations that they made, and they kind of have to figure out and be responsible for making sure that they can connect their own observations to the scientific concept vs. me doing it for them. And for every kid that's a different, that might be a different story that they've told, you know, via their observations or, you know, whatever they chose to test.
>
> So that can sometimes, I feel like it's just more in their hands. And then I'm sort of the person that kind of steps in at the end and helps them make sense of the whole big picture that's under the umbrella. Like they're starting to make those little connections all along, but then it's my responsibility to sort of come in and be like okay, you know, under this umbrella of ideas, I guess, I don't know, but that probably makes sense.

Although the new curriculum has changed the role of the teacher and student, she still feels a strong responsibility of helping the students at the end of an investigation. She finds she needs to help them pull it all together.

> I feel like one of the biggest, one of the hardest parts are connections at the end. We study all these different parts of things. We do this lab and we have all these different observations. And it is, I think I have found, my job at the end to bring it all together for them. Because we used to bring it all together for them at the beginning with the notes and the outlines and the readings and then this when we gave them the answers first. But I feel like now they are kind of out there with all of their ideas.

She described this when discussing an investigation from the curriculum kit. In this investigation, students have to design an experiment around testing if yeast are living organisms. At the end of the investigation, students have observations and other data they have collected, but they struggle to pull it together to make an argument for yeast being alive or not.

> So like I'm, fresh on my mind right now is our fermentation lab where they, you know, they were testing yeast and testing different things that it, you know, would cause it to ferment or go through fermentation, but then at the end they really had to sort of make the connection between, you know, our lab was producing bubbles, but what were the bubbles evidence of? The bubbles were carbon dioxide. What is that evidence of? And like really keep tracking it back to the complicated description of fermentation that was in the reading.
>
> You know, and a lot of them at first struggled to make that connection of, oh, that's what's happening. You know, it's like described all scientifically with fancy vocabulary in the reading, and then in the lab it's like, oh, we mixed these two things together and there were bubbles. So you know, being able to make those connections at the end, I think is where it's kind of give and take, because I have the responsibility of helping them make those connections, but then they also have to sort of be open to seeing and making those connections.

This change in student and teachers' roles is coupled with a change in how the curriculum is learned. Elizabeth noted how the content takes a back seat to broader ideas in science. Rather than focusing on the "nitty gritty," the students study big ideas through several activities.

> Content-wise, I think it's a little bit different, because you have sort of these broader questions, to speak, vs. this like nitty gritty content that we used to have to get through. You know? We get through all these different topics whereas now it's like "how does the structure of a living organism relate to its function?" And then there are three or four different organisms that we're looking at under that sort of broader umbrella, which I like because I think it helps the kids, too… The kids discover the learning on their path vs. giving them the notes and the reading ahead of time and then having them have to sort of figure out where that is in the inquiry. Instead they're doing the inquiry and then all that [the content] comes later…. The kids sort of discover the learning on their own. They're observing and experiencing and questioning what they're looking at. Then later having the a-ha moment of how it all sort of comes together. They're responsible for having to think through what they're seeing and doing with a scientific lens. They have to try to come up with hypothesis or explanations for things before they can get the answers.

Although the new curriculum engages the students in inquiry and connects better with Elizabeth's beliefs in teaching and learning science, she has questioned if there are any trade-offs from the curriculum change. Under the old curriculum, students excelled at memorizing content and making connections within the content—although not necessarily making connections of the content to new situations. As the new curriculum uses discovered scientific practices as a way to learn content, the text for the new curriculum is a lab guide more than a traditional textbook.

> I think they do sometimes lack that sort of disciplined study skill of reading and taking notes. I think we have to explicitly teach it now or at least help them now. Because it was so content based, they were very studious. Whereas now they are very hands-on, do A, B, and C and have to teach them how to bring it all together. I don't know, does that make sense? I mean the kids knew a lot. I mean a lot of content is impressive, I guess. But for what? What's it gonna get you in your future?

She's noted that parents express concern over their child's study skills, as the new curriculum doesn't offer many traditional tests. She wonders if this is a downside to the new curriculum; she wonders if they are losing a skill associated with a more traditional style learning.

> We often talk about how our kids don't need to study for tests as much as they used to. So is that a lost skill? Like, in science I guess, because we're not giving as many multiple-choice tests. We don't have them memorize this and spit it out to me on a test we have three days from now tests. So, I think there is maybe a lack of study skills. Parents get really uptight about that. "My kid can't study for tests." Well I'm like there are no tests in my class. But I wonder if I'm doing them a disservice for them in the future, you know, high school or college course where maybe their line of thinking isn't quite where we are. We've had this discussion about our high school where they still do give them a lot of tests while we're still inquiry, analysis, and a lot of reflection.

Because the style of learning has changed in her class how she evaluates her students has changed. Rather than providing traditional grades, she provides more feedback to her students and tracks this feedback over time. She believes this is more authentic to how science is done.

> A ton of feedback. I love grading. Just kidding. No, I, yeah, the labs have started grading them in any way where I'm just giving them way more feedback than I used to. It takes a lot longer, but I think that is one of the ways that I kind of try to fine tune or pinpoint what a certain student is getting or not getting. So there have been labs where I have, you know, if they are getting a grade on, for an observation section where I have written like paragraphs of like questions trying to get them to like probe, you know, what color was it, why was it that color, you know, just a series of questions, specific questions to help probe them into thinking that their observations could be more detailed or could have, you know, different aspects to them.
>
> So I feel like I'm writing a lot of specific comments to each student based on what they're able to present in their lab. Because each kid is different in that aspect. And then I kind of chart and keep track of those. I score my labs in different categories, and so then I can kind of track in my grade book system, I can track if they're showing improvement in those categories, like maybe you have an observation category or a process category, and then you can kind of see along the way if they're making improvements in those areas and then see if you need to probe them a little bit more.

This style of grading allows Elizabeth to encourage students to ask more questions and engage in additional scientific practices. For example, her feedback may ask students to consider additional ways to analyze data or find weaknesses within their own arguments.

As I've previously stated, the curriculum change resulted in a new curriculum that aligns with Elizabeth's beliefs on the purpose of science education.

> It's good. I mean my, I think my vision has always been that science can be fun, and I think things are definitely more fun when you are hands-on actually performing experiments in the lab vs. reading textbooks and taking notes. So yeah, I mean I think it, there have actually been times where I've had to like remind myself I still need to teach them how to take notes and read a textbook. I get so carried away with like the fun labs and the hands on stuff that will, you know, the next day I'll be like, oh yeah, we didn't take notes on this, we should probably do that. You know?

She recognizes that not all of her students are going to fall in love with science and pursue it as a future career. She joked that when her students were younger many of them probably wanted to be an astronaut but now no longer have that dream. Yet, even for her students who don't pursue a career in STEM, she recognizes a value in what she has taught them.

> Oh yeah. I mean because really if they're not going to be a scientist or go into some scientific career, they're going to take with them all those process skills, all that problem solving, all that sort of knowing what to do when there's a gray area and knowing where to find an answer when you don't know. Knowing how to just, you know, take a stand and back it up with evidence. I think all of that is things that are natural processes that you do in your life all the time, you know, that are just, happen to be, you know, part of the scientific process as well.
>
> So you know, even if you're choosing a career beyond that or not within the realm of science or technology or math or whatever, you're still, you know, problem solving. I think the other thing about science is that it's very highly collaborative. You have lab partners; you have lab table. You know, it's just, in all schools it's like that because you're sharing materials. And science is a very collaborative process. I mean we all know that, you know, whatever, however many percentages of careers that they're going to try for in their future, you know, being a team member, being collaborative, being, you know, a social being, is something that is going to be very important, and I think those skills get practiced in science class every day.

Not so easy as ABC

Elizabeth's experience with the new curriculum has been mostly positive. However, she has experienced challenges and frustrations in teaching it. She loves that the new curriculum is inquiry-based. However, she's found that movements in education are making it difficult to implement the curriculum as written.

> What's happening in education is sucking the fun out of teaching. [Laughs] Like I feel there are so many standards and goals and things that our kids have to meet that we sometimes forget learning can be fun. Like, we have to get this done by this time. I have to have them ready for this assessment by this time. I have to get them through all the curriculum by June. I feel like the pressures of what they're expected to learn can sometimes get under your skin…. I wish we could, you know, skip over this portion [of the curriculum] because that's not very fun. It's kind of dry and boring. But we have to do it! Because we have to, you know, do A and B to get to C. So, I do feel like time sort of is hard and like the expectations of what kids are supposed to be able to do sometimes makes you think you don't have time to be fun every day.

I asked her if she was talking about the Next Generation Science Standards [NGSS]. She said NGSS was not the concern as those standards are improving science education.

> [The standards] make sure that teachers who teach science are engaging in more than just content but in process as well. Processes that, like I already said, are common or necessary in your everyday life, no matter what you do…They also narrow those [content] details…. I think the purpose of them is to sort of have a broader view of the larger topics of science, bigger, more open ended questions… [They] look at science as a bigger picture about the nitty gritty details but the understanding of the big picture of science and how it connects to their world.

Some of the standards she was referring to were the old state standards that existed prior to and just after the adoption of the new curriculum. She felt they were too specific and didn't include the processes or skills that she expects her students to learn. Her state assessed her students' achievement of the old standards with a multiple choice standardized assessment. Although her students always performed well on the assessment, it was not in line with how she taught her class. Her state recently updated the assessment to be more reflective of science practices.

> I think they're trying to be. And I think it's hard because we're so skeptical of them in the first place that, as teachers, we're automatically like ugh. But I think they're trying. I think if we have to have standardized assessments they're obviously trying to make them more reflective of what we're doing in our classrooms. You know. Hit or miss, sometimes. But I often wonder what skill is it that you need.

She wonders how the state plans to evaluate the students' responses on the open-ended items as she struggles grading her own students' work.

> Because it's impossible to grade kids in my classroom. So I can't imagine it on a standardized level. It's, it's...which is why you have to tell the kids, "this is one test, it's one." Because, you know...don't get me started on standardized tests.
>
> I mean grading is so hard now…. It is so hard! And we talk about it all the time. Oh god I have to grade! It takes forever. Oh my gosh it takes forever! There are so many different things the kids can say that are right!

I already reviewed how she graded in the section on the role of content. She tries to balance what she grades on the students' processes, skills, and their understanding of the content that is necessary to reach the bigger ideas. Consequently, she spends a lot of time grading her student's work.

> I'm starting to get to that point where, and somebody out of context might not get my joke right now, but if I have to grade one more black worm lab, my brain might explode. Because I do think like the black worm was amazing and I was excited when we got the curriculum and I'm excited to do it, but now here I am three years later, five periods a year, 130 black worm labs a year, here it is like three or four years later and I'm like, oh my God, I can't do this, I can't grade this paper.

As she continued this thought, she explained how in the old curriculum's monotony (in doing activities or lessons) was easily changed. When she got bored with a topic, she was able to modify it. With the new curriculum, however, she finds that the kits are pretty prescribed and changes aren't easy to make. She feels like her creative side is being held back.

> Because in my old curriculum, when I got bored of something, I would just change it. You know, the content stayed the same but I would be like, oh, let's do this lab instead, where I feel like this one is pretty prescribed and it is kind of, our kit, especially for lack of a better word is a little bit dummy proof. Like here, here's everything you need and here's the procedure and here it is and we're going to replenish it next year so you can do it again in the exact same way.
>
> So there is a little part of like the creative part of me is starting to feel a little stifled of like doing the exact same thing every year. And so I have this sort of philosophical thing going on in my head of like, you know, is what's doing best for children truly that every teacher does everything every year the same way in the same, you know, and I've never been that kind of teacher. I've always been the kind of teacher that changes things each year because A) you want to make them better, or B) you're just like, oh, I'm kind of sick of this lab. Let's do another one.

Sticking to the curriculum plan has also been a challenge for Elizabeth. While she has added and removed lessons over time, she has felt constrained by time. Sometimes the inquiries are very engaging for the students and she wants to keep them going but she finds she has to move on to keep up with the kit. Her classes are only 40 minutes long and it can be difficult to conduct portions of a lesson within that time.

> And then just timing. It's hard, I mean the things that you want to spend weeks on, you just can't. You know, like you get a really great inquiry or you get, you an inquiry and then the kids have all these questions of what if we tested this or what if we put it here, what if we, and you're like, yes, yes, yes. But no, no, we don't have time. So I think that is one of the downfalls, I think, in order to be sort of a true inquiry class. You need to be able to run with those things. But we're, you know, still under the pressure of finishing certain things in the school year.

> I also just some days wish that we could just have science for like two hours. I think I really struggle with the 40-minute period. The way that our schedule works is that our kids are in 40-minutes periods, so I have science, they have science 40 minutes every day. And for some things that's great, but for a lot of things you're just like, oh, if I only had an hour and a half, you know, we could get through this whole process and have like a really meaningful conversation and not have it be cut up between the days and trying to make it work that way when it could just be authentic and happen all at once.

Elizabeth’s schedule isn’t as flexible as it may be in an elementary classroom. Her students rotate between several classes a day as dictated by the school schedule. So many of her activities are often cut short by the brief class periods. A typical lesson for her can last many days. One day could be the getting started, or launch, another day is open exploration to design the inquiry, multiple days can be spent collecting data, and additional days are needed to reflect and review what was learned.

While inquires, and the skills and process that go into them are the main focus in Elizabeth’s curriculum, she still takes time to help the student build traditional skills. She still expects that her students will know how to read a scientific text or cite evidence from a source. But she finds these “not so fun” as she feels they take away from the inquiry experience.

> I’ve had to remind myself I still need to teach them how to take notes and read a textbook. I get so carried away with the fun labs and the hands-on stuff that well, you know, the next I’ll be like, “oh yeah, we didn’t take notes on this, we should probably do that.” So, I’ve had to like remind myself to do the not so fun stuff. But I do. I think it aligns with what we do.

Elizabeth isn't stating that she finds these skills unnecessary. She recognizes that they are an important part of the skills students need for when they are adults. They do need to know how to read factual text, they do need to know how to take notes from someone talking, they do need to know how to cite information. But, if it were up to her, she would be doing more inquiries.

> I would be full on inquiry all the time. I think just, I would probably let them have more say. I try to do that now. But I would let them have more say in what topics we study in a certain, you know, umbrella topic. You know, designing more labs. A lot of what's fun in our new curriculum is there are these labs embedded, we talked about earlier, the data doesn't always pull out the first time. "Oh what happened?" I want to keep doing that. The kids want to do it again: "can we do it again like this?" "Nope! We gotta move on!" [Laughs] You know, I think if I had unlimited resources, or unlimited time for sure, we would test and retest and retest because that's what scientists do. Um, unlimited resources I would just love to go places and be other...go experience other environments or, you know, I don't even know, or maybe bring in more STEM stuff: more building. A couple of the activities I like to do require a lot of stuff that you just don't have the extra money for. But I think I just want to do a lot of more of the trial and error of building things. "Here's a hundred more straws," you know, if the budget were larger. We wouldn't be contained within the budget.

When I asked her about the budget she said she believes she works in a very fortunate place. She doesn't often have to worry about finances as the district provides the science department with an adequate budget. Even so, she and her department have worked to find ways to stretch the budget. The district covered the initial startup cost of the kits, but the restocking is done and paid for by the department budget.

> We've been lucky. I think we've, we've had to sort of give and take in some areas where, things that we feel are more necessary for the learning process vs. things that we could save or reuse or, you know, buy cheaper, or whatever the case may be. I mean I think we've, our department leader has done a really nice job of figuring out like, you know, shortcuts or deals or things where it's like, well, maybe if we reuse these we could save that money and apply it somewhere else. So we haven't had any problems so far with that, no.

Summary of Elizabeth's Findings

The interviews with Elizabeth revealed how she experienced the curriculum change. Her beliefs and practices in science education are aligned with best practices. She wants her students to learn how science is done as those skills will help them as they get older. She stresses the importance of becoming responsible adults. She wants students to recognize their place in earth's systems and realize that they owe a responsibility to the planet.

For Elizabeth, this means teaching science as a body of skills and processes that are refined by exploring large ideas. The content doesn't take the driver seat. Rather, the content is part of the scenery along the drive to becoming scientifically literate. Along this path, Elizabeth has experienced her share of frustrations and challenges: balancing inquiry learning with traditional skills (e.g. reading non-fiction, studying for tests), giving the students more control but having to pull together the lesson for them at the end, time limitations, and having to learn new content that she had not taught before. But these frustrations and challenges haven't hampered her philosophy. In fact, it seemed to make her beliefs stronger as she reified them through the curriculum.

Laura

Laura is an 8th grade science teacher. She has been an educator for seven years and has been in the same school district since she started. However, like Elizabeth, she changed schools. She started her career at the middle school where Judy currently teaches. She served as a long-term substitute in both fifth and sixth grades. After that year, she took a fulltime science position at the junior high school where Elizabeth and Delores teach.

Laura felt she wanted to be a teacher from a young age. She feels that this desire to work with children is partly rooted in her positive experiences with school growing up.

> I loved school. I liked learning and all of my different classes. Teaching is something that I've always wanted to do as a young kid. I just really liked working with kids. I liked seeing them learn and seeing how they problem solved. That led me to science, too. My mom went back to school when I was younger. So I walked through the process with her. That was cool: to see her going back to school and helping her with her classroom.

Science wasn't a topic of interest for her until she started high school and college. She enjoyed what science offered her in those grades.

> I didn't really particularly like science until I got to high school and took chemistry. That's when I started to really like it. Conducting chemical reactions and just seeing the math that goes into the science as well really intrigued me. Projects like the egg drop when I was growing up—that was good! That was fun!
>
> Then in college I took a couple of teaching science literacy classes that I absolutely loved. I think that really sparked my interest.

Laura enjoyed the structure of her college science courses. Many of her science courses were designed for teachers. She described the classes as introductory but with teachers in mind. Some of the classes were clearly inquiry oriented while others were still taught with a traditional framework.

> I took some kind of science literacy and methods for instruction, but I took a geology for elementary teachers and a physics for middle-school teachers. I took a standard biology 101 and a standard chemistry 101, but most of the curriculum was geared towards teachers.
>
> I think the classes for teachers were more focused on how we get from point A to point B and what things we need to think about and consider, whereas I felt the classes that were 101 or 202 were more like this was just the background step for where we're going next for bio or whatever.

I asked Laura to elaborate on what she meant by her classes focusing on getting from point A to point B.

> For us it was more about how—we figured out how we pose a problem. We would then—they took you through—it was less guided instruction. Whereas when I had my 101 class, it was like this is the question, here's the procedure, or you need to develop your own procedure to get his result. We knew if the results weren't what we expected, we'd need to go back. Whereas in the other course it was more of a—we felt we were doing something new, even though it wasn't.

Her experiences in college framed what she believed was the best way to teach. She described her philosophy of teaching as believing all students can learn and that the students should be given the lead in their own learning. She found that part of this philosophy was from her experience working at a day camp.

> I think working with kids, even in day camp, you see kids jump out and do things you wouldn't necessarily anticipate them doing at the beginning of the summer. And so I think that all students can learn. When you give them the bare bones and excitement for learning and encouraging lessons and provide proper guidance and proper scaffolding, everyone will succeed and grow.
>
> Being a science teacher is to be a guide and a facilitator, to promote—just trying to promote those practices even in and outside of the classroom, thinking in scientific ways with how you engage with your friends and how you enjoy your time. You use it in everyday life, and learning those practices are going to take you—it's used in every discipline of every area of your life.
>
> It's part of life, and it's a part of growing. It's applicable, no matter what subject you're in. The scientific process is something that's not just done in the classroom. It's done everywhere else, too. It's incredibly important early on, and especially throughout their educational career to really reinforce those skills in class as they can use them outside.

She believes that children are naturally curious about their world. She believes science extends that curiosity. She wants her students to learn that scientific practices are applicable outside of science itself. Ensuring her students engage this curiosity is done through differentiation.

> I try to differentiate. I try to leave open-ended tasks so students can make it as complex as they feel they're able to do. Then also I'll give different tasks. For students that feel they're ready for the challenge, they can choose to take something more challenging or more structured.

> I think science lends itself really well to this because the act of science is to be engaged and making those choices and decisions. It's the easiest subject to differentiate.

Laura feels that she is equipped to teach science. The practices that are necessary are one of her strengths. She has gone beyond her undergraduate degree in elementary education to make improvements to her teaching. This included becoming a National Science Teacher Association New Science Teacher Academy Fellow and completing a Master's of Science in Science Education.

> I did a program specifically for young science teachers. That had an online platform. I had a mentor that was a science teacher. It was just a great way to bounce ideas off teachers who had great experience. It was also a way to make sure I was keeping in line with the practices that were being researched then. That was a year-long mentoring program. Then, I also did the conferences themselves, which were a couple days long—very helpful. It was a nice thing to boost enthusiasm and a new interest in different areas.
>
> The Master's program was geared specifically towards middle-school teachers in science education. It was a very well run program. I thought they did a nice job of giving us content in all of the broad content areas of science at the same time as evaluating different curriculums and finding the mode for how we teach the process.

Seeking professional development has been important for Laura. She feels the options she has selected have been helpful. But she wishes the district would provide better professional development opportunities for her and her colleagues as they once had. Now she feels the professional development is too structured.

> The PD I took were a lot more targeted. I felt they were speaking more out of experience. They're better organized—well thought through. Some of the general courses offered by our district have had some excellent speakers. They've had some speakers on thought process and thinking, science of the brain.
>
> It was nice in that we were able to go off on our own and were given a little bit less guided work to do. It was a little bit more meaningful than what we had done in the past and what we do now. We worked as a department, which was great.

Content is King

When discussing the value of learning science, Laura highlighted the joy students have when engaging in inquiry. She talked about how the students are excited, eagerly participate, and even try to replicate activities at home. But, she noted, when the focus is primarily on content instead of process, the students seem to lose that joy.

> I think the interest is just gone. You're not interested. I feel as soon as it comes down to you have to remember this—facts and figures—the meaning is just gone. It doesn't become personal anymore. It's more general.

This was hard for Laura because she believed that science is meaningful. When the curriculum doesn't provide that, she feels the students are disconnected. Unfortunately, prior to the new curriculum, Laura was given a curriculum that was fact driven and disconnected from the students. The old curriculum was a textbook, lab driven understanding of physical science. Laura said the topics studied included conservation of mass, density, volume, and characteristic properties of matter. The curriculum culminated in a weeks-long project called Sludge. The students had to isolate all the individual components of the mixture using the skills and knowledge they had learned throughout the year.

Learning these topics was not engaging for the students. Laura commented on how the textbook and labs were not open-ended.

> The curriculum was definitely more closed-ended. There was a pre-lab, where we talked about how to do a lab. They do a lab. Then we talked about what you should have or what should be found at the end—what we did find. It was not inquiry oriented. It was all about the content.
>
> It was not as easy to differentiate. It wasn't as open-ended, so there was a greater need for you to scaffold out the parts that are really important in science with a traditional curriculum.

This was a challenge for Laura. She wanted all of her students to learn. She wanted to provide opportunities for all of her students to participate in class. Yet, she found the old curriculum did not readily allow this. Part of this was due to how the curriculum was structured. Most of the time was spent lecturing to the students or participating in whole class discussions.

> It was much more content-based as opposed to activity. I think we had—on a good week it was two periods of lab and three periods overall of discussion.
>
> It was mainly, as far as content, mostly from the lectures in class. We would always take the class data and draw conclusions from the class data. As long as they have the class data and it was okay, they could probably come to the conclusion that they needed. I did appreciate that it was data-driven. I liked that. But, it was too guided. It was too given.

While there was data to process in class, Laura felt the data was too structured for the students. There wasn't an opportunity to engage in messy data. When the students did encounter data that was not consistent with the results of others, Laura said they didn't have time to discuss it because they had to keep moving. "I don't think we had much opportunity for that," she stated, "because we had to be on target at certain points in the year for different projects. There wasn't too much time to stop and reflect."

The students spent a considerable amount of time trying to match their findings with the expected outcomes. I asked Laura why she thought the curriculum used labs. After all, if the students are simply trying to match the outcome, what is the purpose of doing the lab? Couldn't they just be told the right answer?

> I think it was just to—I think they wanted them to go through the process of this is what a lab is and this is what a lab looks like. So, understand that process and doing it. But looking back it was more of an activity. Some things we could've just talked about and moved on to something deeper.

Consequently, the students didn't have the opportunity to engage in more scientific practices. They weren't encouraged to ask questions, they weren't allowed to investigate topics further, and they weren't able to reflect much on their learning. The students just couldn't connect to the curriculum.

> The students were observers. It was more teacher-directed. They would listen. They would ask questions. They would do the lab as it was told and then get the results that they should have gotten. It was a lot more teacher-driven.
>
> Students didn't really care how to find the volume 19,000 different ways. It wasn't really posed as a good problem so the interest wasn't there. I don't think it was really how science is done outside of the traditional classroom. It was a poor representation of that.

Laura recognized that changing the curriculum was hard to do. She would try to make it more relevant and meaningful for the students. But, without a real connection to the students' lives, she found that difficult. She talked about how she'd modify the curriculum by adding challenges or building in extensions. But, as she previously mentioned, this was hard to do because she was under a time crunch. There was not a lot of flexibility within the curriculum to stray from the book.

She tried to integrate more scientific practices into the curriculum. For example, she challenged the students to write their own procedures. She tried to develop essential questions. But the curriculum's content and time restraints made that difficult to do. It took too much time for the students to develop their own procedures. And, if they made mistakes in doing so, then they wouldn't be able to reach the expected outcome.

Laura's overall perception of the old curriculum was negative. The curriculum seemed to be at odds with how she believed science should be taught and why the students should learn science. I asked Laura what it was like when she started teaching the curriculum in eighth grade. How well did it fit in with what she learned in her college classes?

> It felt like I was stepping back in time to my elementary school experience of science. I had to revert back to those poor experiences I had growing up. I think this curriculum was created in the '60s or something. It was a time when education was more industrialized. You have to get from A to B, pump the information, get as much as you can, and move on to the next. Whereas now we're realizing the process is more important. I think it was created in a time that doesn't reflect what we know about education now.

Laura realized that fixing this was going to be an undertaking. She wanted the curriculum to be inquiry-oriented. But her attempts to do that to the old curriculum seemed fruitless. The entire curriculum had to be changed.

> The old curriculum was becoming more and more aligned with how I felt science should be taught, but I still wasn't really happy with it. I still felt there were so many foundational things that were flawed and really couldn't be rectified without overhauling the whole system.

Fortunately, the overhaul was underway and a new curriculum was about to be implemented in her classroom.

Desiring More

Laura had eagerly anticipated the arrival of the new curriculum. The timing was perfect. The prior curriculum was out of date, not engaging for the students, and was grounded in a teacher-directed style of learning.

> The curriculum hadn't been updated for nearly 30 years. They'd been using the same package for that entire time I think. And so it was just timed—there was also new standards that were going to be, that were coming out with the Common Core. And the NGSS that hadn't fully been developed by then. But the district wanted to approach those proactively before.

Although Laura wasn't a member of the committee that was working on revising the science curriculum, Laura was able to participate in providing feedback.

> Along the way we would get things and modify them as we went. So we did have meetings where we would look at what the committee had developed so far and we would tweak it and then send it back.
>
> Our biggest concern was that the new standards had not yet come out. So we were kind of anticipating what would happen with those new standards. And so kind of meeting those while at the same time making sure that we had covered everything throughout he K-8 curriculum content-wise.

Laura learned she would be teaching three new curriculum units to replace the one prior textbook based curriculum. The kits included 3 units from SEPUP and supplementary materials from the NSTA. The district had originally planned to offer training to Laura and her colleagues at the same time they were first implementing the curriculum. Delores fought back on this and ensured Laura, herself, and their other colleague would be trained before the current school year ended. The training that was offered was not as great as Laura had expected.

> So we had—we have three different units and we essentially had maybe half a day or a, I think it was half a day for each unit where we had someone from the textbook company come in and kind of walk us through maybe a couple of activities, general themes. It was kind of a quick run through. We were given a little bit of time to kind of develop ourselves, so kind of look at it, and that was the most valuable time—when we were able to dive into it independently and cooperatively as well.
>
> It was helpful, for sure. I mean, it didn't, I was never, you can't fully be prepared, but I do think it was helpful. But, it didn't really feel targeted. It was, it felt a lot more scripted. So we came with some concerns that the curriculum was not challenging enough for our students. And we prefaced our training with that. But it didn't seem like it was adequately addressed in our training.

Laura's concern about the curriculum materials being too low didn't seem to faze the trainer. Laura said that the trainer gave some ideas, but she felt the ideas were a canned response that would be told to anyone. She didn't feel the training was specific to their school and her students.

I asked her to discuss how she felt about the content of the new curriculum and how it compared to the old curriculum.

> I think the content level in all of them were lower than what we had anticipated. The amount of things that we needed to cover was significant. The content itself. But the depth of knowledge wasn't—it didn't match necessarily where we found our students to be in the past.
>
> I think the depth of knowledge would be more. The knowledge has a greater impact on student achievement, learning, and understanding. So, I would much rather, much rather go deeper as opposed to covering a lot of content, shallow.

Laura was not excited about how much content she was expected to cover. Although the new curriculum was inquiry-oriented and had a focus on scientific practices, she felt the topics were addressed too shallowly and did not allow the students to dig deeper into the ideas. Laura did recognize a benefit in that, though. She saw that having many topics to explore, versus the one topic of physical science in the old curriculum, would allow her students to feel successful.

> The old curriculum was so narrow. The focus itself was so narrow that it didn't necessarily allow for differentiation of like abilities. I felt like with this new curriculum students were more able to kind of really approach each lesson or whatever with, at their ability level. There's so many more topics that the kids—that they had trouble with maybe one, you know. They would have to take it as a possibly lower level. But if there's a similar one that they were really engaged with, excited with, they could do a higher lever than that.

She found the new curriculum to be easier to differentiate for her students. When students struggled in the old curriculum, she found they continued to struggle since the topics were cumulative. In the new curriculum, however, a topic is only addressed for a certain amount of time. If a student struggled with it, they'd only do so until the next topic was introduced.

While the amount of topics to cover was larger, Laura appreciated that all three curricular units shared a common thread: a focus on certain scientific practices.

> I think our written and communication piece was something that tied all three units together. Writing and communicating clearly, kind of assessing data was a common theme. Those were the two that really drove home. The new curriculum was more varied and allowed the students to see the data analysis and communication in different ways than if you just had one standard topic all year. It was more applicable to a wider range of science.

Laura found the lesson format of the new curriculum to be reflective of scientific practices and what happens in the scientific community. She described a typical lesson format.

> There was usually some kind of like brief introduction into like what do we think about this, what are some questions that we could ask about this, and then was, there was an extended period of kind of discovery and experimentation, manipulation. And then we would come back together and look at the data that we had collected, the observations that we had, kind of come to a conclusion, not necessarily a full conclusion, but one to refine a little bit. And then, kind of back to the students. I hate to use the word find again, but they would find their understanding and then reach more of a conclusion at the end.
>
> I like to think that's exactly what scientists do, right? They develop their own questions, they experiment and they refine. There's a lot of collaboration that goes on. And I feel like students have more ownership, just like scientists do in that way. Yeah!

She compared this to the previous curriculum and noted the general format was the same. But, in the new curriculum, students were encouraged to refine their ideas and thinking based on what they had discovered. In contrast, the old curriculum provided little opportunity to refine their knowledge.

As a result of the curriculum being inquiry-oriented, Laura recognized her role and the role of her students had changed. She found the students to be more engaged and hold a bigger share of the investigative responsibility. She found herself to be more of a guide than a leader in the classroom.

> The students were expected to actively engage. So they were the ones that were making the questions, they were the ones that were carrying out the experiments, designing them, and coming to their own conclusions. So the teacher was kind of,

> there was less of the teacher in that. The teacher was more like a guide, a questioner, to help kind of focus the students' ideas and the students were more active.

Laura admitted that this new role for her required more planning and preparation. As there were many routes the students could go, she realized she would have to be prepared for where they were going. But, that led to an important benefit: the students were engaged and got more out of the curriculum.

> It was more, it was exhausting. I think, yeah, because you have to plan and anticipate what misconceptions might be coming up. There's a lot, the curriculum wasn't so narrow and defined. It was more. There was a lot of opportunity for, for new things that students could discover. So it definitely required a lot more planning upfront. And it was, it was exhausting. But the same time, I felt like students got a lot more out of it.
>
> Initially it was rough, but once I kind of understood what students, what problems or issues students might encounter, it becomes more, like just with teaching, too. You know, as you teach longer, you know what to focus on and where to steer.

Laura was also happy with the new format of the curriculum because the role of content changed. In the prior curriculum, content was king. It was the focus of learning. The students had to reach the same outcome as the teacher's book to learn. But with the new curriculum, content took a back seat.

> The content was definitely there in the new curriculum, but it was a little bit more in the background-ish, in that students kind of had to discover it through multiple activities. It wasn't in your face. It wasn't, you know, stated right away.
>
> It was more investigations and kind of probing questions. There would be small sections, you know, a small chapter here or there that would have some more content. But it was mainly the investigations.

In teaching the curriculum for the first year, Laura wanted to stick to the curriculum as it was written. The new format, as she noted, was exhausting. But as she and her colleagues taught the new curriculum, they felt there were just some pieces that were missing.

> In the first year we kind of stuck to just the Lab-Aids curriculum. And while I felt that it was, I mean it's new and it was nice, I felt that students were a little bit more engaged with what was, what we were covering at this point. I didn't feel like it was everything it could have been. It felt like the connections were still fairly, they were better but they were still kind of weak. So, I felt like it definitely had to be supplemented.
>
> So as we were reviewing the curriculum, we noticed that there were definitely some gaps. So, that's when we pulled those materials in and then we've also kind of along the way have added in other things, too.

One of the areas where the curriculum was lacking was the personal connection. While the new curriculum was more meaningful for the students and approached learning through issues and problems, it could benefit from making local connections. Laura shared that some lessons, "could adapt to like our backyard," and make learning more relevant for the students. She also found that current events needed to be tied in.

Laura and her colleagues appreciated that they were all able to tailor the curriculum. Laura shared how she and her colleagues would meet to reflect on what they were doing with the lessons so they could make improvements. Sometimes colleagues would skip a lesson that she would teach. Other times she would revise a lesson to make it more inquiry oriented.

> We did a lesson with macroinvertebrates and using them to determine water quality. I think initially I had, kind of stuck in my old ways, like taught students like this is what you look for, this would be really good. Whereas, I kind of developed and grew as a teacher, I just kind of presented students with this is what we found here and this is what we found here. Why might they be different?

When NGSS was formally released, the district asked Laura and her colleagues to review the curriculum map to ensure it met the standards. Laura appreciated this process, and NGSS in general, as it helped them further refine the new curriculum and hone in on its inquiry aspects.

> I think NGSS wants students to be a little bit more, not necessarily college ready but kind of like life ready, if you will. So, something that's more applicable to everything that they encounter. Yeah, more focused on problem solving as opposed to just content. Because that can be applicable over, over a lifetime.
>
> When we had gotten the curriculum, the drafts had come out a couple of times, but it wasn't, it wasn't the full, the full piece. So, I think it was a year or two years into our curriculum that we were able to go back and refine. So, there were small units we could cut out and fill in with other things that matched those new standards.
>
> For example, I think specifically in genetics there was more of an emphasis on proteins and their functions as opposed to, you know, the specific makeup of DNA. So, we focused more on like the bigger picture, not necessarily the naming of all the individual components. More of the like structure and function.

The new curriculum permitted Laura and her colleagues to make changes because it was focused on scientific process rather than content. In her genetics unit, attention was diverted away from knowing the names of all the nucleic acids and instead focused on recognizing the structure and function of DNA and proteins. This connects to one of the broad disciplinary core ideas in NGSS.

A challenge in implementing the curriculum is the structure of the day. Laura wished she had more time to implement the curriculum as it was written. She found that her 40-minute class period was not conducive to inquiry learning.

> What's been challenging is we have a 40-minute block period. Sometimes it'd be nice to have a little more extended time. We have great lab space, but I think having something nearby that's outdoors, so we can explore more local ecology. We have quite a bit of flexibility right now in curriculum and planning, but that would be a great bridge to build on.

She reflected on how she could use a longer block of time by having her students experience the outdoor classroom at her building. She shared how she had the chance to do this in her master's program and it gave her investigation ideas.

> Allowing students to maybe do some studies on what's out there. Some kind of modifying of—if they want to test the effects of—it would have to be within

> parameters—but the effect of X on the environment. Something with a practical application.
>
> In my master's program we did a lot of walking outside and finding different plants and species, and observing what was around and why that was. That was a really cool thing, to look at our local environment differently.

Summary of Laura's Findings

Laura had positive experiences with science and school in general while growing up. Her decision to become a teacher was due to her enjoyment of helping kids learn and providing them with skills they could use throughout their lives. Laura's experience with the old curriculum trapped her within an outdated style of teaching. She was aware of inquiry learning but struggled to find a way to make that happen within the old curriculum. Its focus on content and its limited flexibility made Laura teach in ways that were not congruent with what she had learned in her science methods courses in college. The old curriculum was not inquiry focused, it was content focused. She taught by telling her students what they needed to do in the labs. Her students had to reach the right answers. Most her teaching was spent in lecture and discussion rather than engaging in scientific practices.

The new curriculum, in contrast, was inquiry oriented. It allowed Laura to teach in ways that matched what she had learned in college and through her continued professional development. She was excited for the change. When she first taught the new curriculum, she followed it closely. However, the more she taught the more she realized that it was lacking in certain areas. She modified the curriculum to make it more challenging for her students. She added and removed lessons based on how important she felt they were relative to the students' lives and in meeting NGSS standards. She made the curriculum more relevant by localizing the learning experience and she made it address broader concepts based on NGSS rather than specific content information.

Delores

Delores is an 8th grade science teacher in a suburban school. She has been an educator for over 23 years, 14 of which are with her current school district. In her current school district, she began as a math and science teacher in sixth grade before moving to 8th grade science full time. Although she has recently been teaching science exclusively in a public junior high school, she has previously taught a variety of subjects (math, science, and drama), in public and private schools, and students who are at-risk to those that are gifted. She also has a bachelor’s degree in biology. She has taken numerous college courses past her bachelor’s degree and has amounted more credit hours than that which is required for a typical master’s degree. In addition to this she completed a master’s program in science education.

Delores was the co-researcher in the pilot study for this dissertation. I chose to re-interview her for two reasons. First, her experience in being on the committee that structured the new curriculum map is unique to this study. No other co-researcher served on the committee. Second, when the pilot study was conducted the new curriculum had yet to be finalized. Although the map had been created and finalized, the kits would not be implemented until the following year. Interviewing Delores again for this dissertation allowed us to see if her beliefs about the process had changed and to understand what her experience was like having implemented the inquiry kits. Additionally, re-interviewing

Delores added trustworthiness to her findings as her re-interview mirrored what she explicated in the pilot study.

Identity: A Source of Inspiration and Guidance

Delores recalled how she did not like school. It was a result of teachers she felt did not do a good job teaching.

> So in third grade I had a teacher who was awful. She thought that you should do the same worksheet over and over again until you got a hundred percent on it. And I thought to myself in third grade 'I can do better than this.'

This negative impression of school was overturned when she took her first science class in high school. Her teacher had a positive impact on her that made her love science.

> I had this awesome science teacher…. He loved teaching, he loved biology, and I [felt] like, 'Oh my God! This is the one thing that I understand.' It clicks with me. Science. Who would have thought? Because it…my middle school experience had been all reading out of a book, no labs. And then you get to high school and all of a sudden you're doing all these labs. I get this! I like this dissection and I understand these cells. This is wonderful!

This teacher and his curriculum allowed Delores to find meaning in science. This discovered meaning and connection was so strong that nothing was able to change her love for the subject.

> I got this grouchy old swim teacher for biology…. I remember he was a coach and he was 'grough' and kind of bleh. But I still loved it. It didn't matter because the other teacher had hooked me. And I got it. And I loved it.

Having fallen in love with science it was not surprising to hear Delores say that she continued on to study science after she graduated high school.

> And so, biology, since that was the one that clicked, I said, 'I'm gonna do that.' I love it. […] I got to take bio. I got to take genetics. I got to take, um, you know, anatomy and physiology.

I asked her to share some of her favorite classes she had in college. She talked enthusiastically about her most meaningful and memorable experiences. One of these experiences was a semester long class done in the Bahamas.

> [My] favorite classes that I talk about a lot that I had at a community college was called Bahamian Ecology. And so what you did was you studied for the semester…yes, the semester, um, organisms that live in the Bahamas. We went and lived on a sailboat for a week. We had two sailboats that were connected together. There was a class of like twenty of us. And we sailed through the um, part that's protected in the Bahamas. We snorkeled and we…catalogued everything that we saw. If we saw something that we didn't know what it was, we would go look it up. We got to go onto islands, and look at different kinds of species, including plants and animals and insects and all kinds of things. So that was an amazing experience, which I've never forgotten.

This experience was powerful to her in establishing her identity as a scientist. She was able to engage in scientific processes and learn through meaningful experiences. Similarly, her identity as an educator has been undergirded by a number of careers that involved education.

> I would think, you know, my whole life I've either worked as, and you as well, a camp, a summer camp person. Right, after school person, pre-school. I mean, every job I've ever had has been in a school or a pre-school and then, of course now I've been teaching.

In discussing her background, the emotion of love often emerged. Love was not only an important influence in her life as a scientist but also as a science educator. She believes that love is essential to her job.

> Here [at the junior high] it's about me imparting knowledge to them, about science. Which is what I want to talk about all day. And I think that's really important in our profession: to stay that enthusiastic about it and say, you know, I do this because I love this. I start every year like that and I hear you talking to your kids and you do the same thing. You know? I'm here because I like it.

Her identity as a scientist often conflicts with how others view scientists. She reflected on this in a lesson she used to do with her students.

> I used to make my kids draw scientists. And then we talked about stereotypical people. And so then I have actual data on how many people draw a scientist with glasses, how many people draw it with crazy hair, big heads, lab coats, those kinds of things. I used to always say at the end of the lesson that I'm a scientist. And I'm also a teacher. So I classify myself as a scientist.

This lesson was important to her because she wanted her students to know that scientists are not just the stereotypical image of a crazy old man in a laboratory. She was a scientist and concomitantly a teacher. Although her primary role is as an educator, Delores' background in science has allowed her to create her identity as a scientist. It was important that her students knew this.

Professional Development: A Means to an End

Delores connected the value of staying up to date with her definition of a scientist. Thus, in identifying herself as a scientist, she held the idea of professional development as central to her identity. This became evident as she discussed how her enrollment as a graduate student at a local university assisted in maintaining her identity as a scientist.

> [My master's program] has made such a huge difference to me because I feel updated. I, I feel like 'oh my gosh' I am finally getting the updates that I need.

In her classroom, Delores felt she does not stay as up to date as she needs. She believed it difficult for educators to accomplish because they are trapped in their classrooms. One way for Delores to stay up to date is to have professional development. The impact it has on her is powerful as it strengthens her identity as a scientist.

> Although, until I came back here to [my master's program], I haven't really felt like a scientist. So, really being here [at the university] helps me. I am a scientist. And I think that it's just a hard, it's a hard thing when you're stuck in a classroom for a lot of years without any kind of…I mean we have great professional development in our school. But it just doesn't really go for what we need [in a] higher level of education [for ourselves]. We get stuck in that middle place and it's hard sometimes. I think being a scientist is learning and being up to date. And, I just, I just haven't done that

> a lot lately. And our professional development in our school doesn't do that until recently.

Professional development opportunities in her school district have been lackluster. When asked about the professional development she used to receive, prior to it becoming better, she offered this simple answer:

> There's been nothing valuable in this district as far as professional development in science until we started planning our own professional development.

This lack of professional development coupled with her love of science encouraged her to go out and find her own opportunities for growth.

> The professional development that has been valuable for me has been the things that I have sought out for myself here. I'm also hoping to be part of a pilot this summer on the new Next Generation Standards.

This is not the only professional development she has sought out. When she lived on the west coast she attended a yearly science teacher's conference. One year she presented at the conference. Further, Delores discussed how she and her department have taken control of their professional development through a new initiative in the school district.

> Previously in the district people had, um, planned…our professional development had been planned for us. Now we have these PGNs…PGCs? Those are professional growth communities or networks. We have these professional development days where we decided together what things we needed to be trained on or in what areas we needed enrichment. We had a university come train us on a computer program, which is going to be great for our new genetics unit. We took a trip to a museum to be trained on, um, experiences through them…uh, what kind of things we could use for us…how we could use the museum in our classrooms.

She found the new model of professional development to be beneficial. With this new opportunity, she took an interest in focusing on professional development related to technology. She focused on technology because it has become such a part of her students' lives. She felt compelled to learn how to embrace it and bring it into the classroom.

> SmartBoards and computers and I, I mean, I definitely can do them, but I, I you know. It's hard for me. It's not something that's ingrained like our students. Which is okay 'cause my students can just tell me how to do it.

While integrating technology is a way for her to stay up to date—and therefore a way to keep her identity as a scientist—she struggled with the push to make technology front and center in the classroom.

> Elizabeth and I were sitting in a conference. And the purpose of the conference was 'here are all the great science websites and here are all the great science apps that you can use.' She leans over and says, 'I do that, but do it for real.' You know, here you go: you can dissect an animal on here! But, we, we do that for real. That's great as an alternative who is against the dissecting. However, we want kids to still experience. I hope the technology doesn't take away from the hands on experience.

Technology is something she felt supported with in her school district. Unlike other avenues of professional development, staff members fully supported technology integration in her school and the district. She reflected on this as she compared her own technology resources to teachers from another school district.

> All the technology love I get in my classroom comes from our tech teacher. She is the goddess of technology. I mean, number one just to have computers to check out. Number two to have a technology person to sit down and plan a lesson with. And then, number three, it's my own belief that science needs to involve technology.

She was very grateful that her school has technology resources available, as she believed it supports students' learning of science. Although the new model of professional development has proven to be beneficial, Delores still encountered hurdles. For example, she and her department wanted training on the new curriculum a year prior to teaching it. Yet, she discussed how it was a battle with the district to secure that professional development.

> They said they can't afford to do all of this [training] at once. They had to roll it out. This was the plan. This was how it was going to work. There was no flexibility. I don't know why that [district agreed with Delores] happened. I know somebody sent an e-mail, uh, regarding we really want to be trained before teaching the new

> curriculum. I know that the seventh grade teachers and I both had a lot of concerns about waiting until we were teaching the new curriculum to be trained on it. And we had already voiced those, but those concerns didn't go anywhere.

She felt that this contradicted the new professional development model. If teachers know what is best for them, why does the district not respond to their request for professional development? She believed it was a lack of trust the district has in its educators. She struggled with this because the district often recognizes Delores and her department as being experts in their area.

> I don't think our district has a really good sense of, um, the science knowledge our science department has. I think that they appreciate that we are experts in our field. But that sometimes [they] don't trust us with our thing because we… One of the things that we really wanted was to be trained the year before we started the new curriculum. We didn't want to wait until the next year to be trained. I don't know why they don't think that we couldn't be trained on something the year before and not remember it next year. That's ridiculous.

She and her department repeatedly requested training the year before so they could become familiar with the new curriculum and have time to modify it to their students' needs. She discussed how she and her department had to fight with the district to get the training they needed. Delores reflected on how difficult it was to get the district to change their mind about training. It took the department meeting with the superintendent to get the training a year prior to adopting the new curriculum.

Change: What Drives Delores

Delores held the idea of change as important. This is because it reflected how science is a changing discipline and the needs of her students change over time. This change was visible in how Delores designs lessons and teaches her students.

> I'm trying to incorporate 21st century learning. I'm trying to incorporate my technology. If somebody didn't pressure me I think I'd stay with the same old lesson

> I did last year. And the funny thing is let's take three years of lesson plans for me and you will never find any of the same.

She frequently changed her lessons throughout her time at the junior high to make them more relevant and engaging for the students. There was a lesson the department did with all her students. It was called the egg drop. It's a classic science lesson in which students must design a device that will keep an egg from cracking when dropped from a certain height. She was unhappy with this lesson because it was done in a nonscientific way. She discussed how she tried to improve it.

> So the one thing that I was able to do and that I have changed was for my own class, but I haven't got everybody to change was, um, scientific method. Like, the thing was, the teachers before me would throw them, um, down the classroom, then they'd throw them downstairs, then they'd throw them out the window. But they'd never open them in between. So, you don't know ever where they broke! And they would also have different people throwing them. So, the problem, there were so many problems with that. It doesn't even seem like an experiment.

Her solution to this was to approach it from an engineering standpoint. She had the students design the devices using engineering practices and they tested how well their devices worked. She felt this was more reflective of what happens with science and engineering practices.

Delores also created new lessons in addition to modifying old lessons. She introduced a lesson on Rube Goldberg machines, an elaborate contraption that performs a simple action, such as blowing out a candle. She introduced this new lesson because she was tired of the old curriculum. The curriculum did not always align with her values and identity as a science educator.

> I think the reason I brought it in the first year is because I was so tired of our curriculum and all I had to do was lecture. There was so much lecture. And they do a lab, and then I'd have to lecture about it for two days. And they [students] just hated it.

The lesson she created was integrated with social studies and their exploration of the industrial revolution. She enjoyed changing the curriculum to reflect her identity and the needs of her students. But, changing the curriculum was quite a challenge. She recalled how she was the only teacher in the department who questioned the curriculum and how it was taught.

> The last time it went through review the teachers that were here were very set in their ways. And they refused to change the curriculum, even though it needed updating. So, technically, our district, our science program…no, not technically. Truly, our science program in our grade had not been updated in twenty years: two-zero.

Delores was upset with how long it had been since the curriculum had been updated. Other grade levels had their science curriculum update about ten years ago. She remarked on this stagnation: "in science, that's just frightening." She said this because science content is constantly undergoing change: new information is added and old information is updated or removed. Plus, the ways to learn about this information has changed. She was in disbelief that it had not been updated.

When she was hired at the school, she was looked to as someone to begin the change process. The administration seemed to know that the curriculum would not be updated unless a new person was brought into the department.

> When I came here, the principal made it very clear to me that he was looking to me to make changes. And so I was unpopular from like almost the minute I walked in the door. So, um, because these guys had been teaching this for thirty years or more…between twenty and thirty years for all three teachers who I was joining. So changes were not looked upon lovely. […] If those three teachers wouldn't have been retiring then I wouldn't have been able to change it.

It was hard to begin the process to review and change the curriculum. But she knew that this process would have to start with her, in her classroom.

> So I asked the district to send me to, to be trained on this thing. And I actually got to meet the author of the book, and hear what his actual ideas were on this curriculum, and I came back and I was a better teacher on this because I had learned it in a very traditional way that didn't really match the book. And then, once I learned from these, they trained me, I, I learned it better in it, and it went much better for the way I teach.

The veteran science teachers had trained Delores on the old curriculum. Their teaching pedagogies were too traditional and too teacher-centered for her. So she sought out ways to improve her teaching practices and the curriculum. As the veteran teachers began to retire, she started to advocate for a new curriculum for the entire grade level.

> They [district] decided to make it a two-year committee. And, in that two-year time, we went back over the entire map for the whole district to make sure kids were getting everything we hoped they were getting in science, including the current framework. […] We first reviewed everything that we had in the district and then we started breaking it down making sure it was in the right place.

Part of the struggle in designing the new curriculum was finding the best fit for her students. Delores was astounded at the lack of available resources.

> So, actually, the balance was terrible because it was all experiments with no background, no reading, no nothing. Not that I feel like the kids have to read but there was just nothing. Like I, I would never let the kids study for the test just using their book because the book just had nothing. We taught five chapters from this book, which was only a hundred pages for an entire year. So really, I didn't think that was good at all.

In changing the curriculum, she wanted to make sure that she would be able to find anything that would be better for her students: more student focused, more and varied resources for her students, and more meaningful and authentic learning experiences.

Meaningful Experience: Finding the Perfect Curriculum

Delores struggled with teaching a curriculum that did not provide meaningful experiences to the students. Her old curriculum focused on physical science. Students identified characteristics of materials and conducted labs to discover scientific knowledge, such as the law of the conservation of mass. She reflected on how difficult it was to find meaningful connections for the students in the old curriculum.

> There aren't a lot of connections. I'm, I'm grasping for often…I'm looking for an article that has anything to do with anything we're talking about. I mean, they are good principles, you know, however, how often does a person walk around and need to know a characteristic property? They really don't. They don't need to know the densities of stuff. […] It's just a struggle. It's a struggle. It really is.

While it was hard for her to find connections for the students, Delores did have some successes with aspects of the curriculum she taught.

> The experiments were great. And, I'll still use some of the experiments next year because of the way they're setup. Like, okay fourteen people in the class are going to gather data on this, we're going to put it on the board, and we're going to try and figure out, for instance, what the boiling point of this mystery liquid is by using everybody's data, you know and graphing it.
>
> And I love it when we get to solubility because we can talk a little bit about water. And also separating mixtures we can talk a little bit about petroleum. And we can talk about fractional distillation and petroleum. And so, um, I like the water aspect we can talk about acid rain, we can talk about what's the difference between distilled water and real water.

Delores found a connection for the students through water studies in the new curriculum. She described why the new curriculum was better as it employed more connections and allowed the students to walk away with a better understanding of science and their world.

> There is science for knowledge of the world. And I think that a good portion of my kids [...] just need to have a basic understanding of life. How things work and you know, what would happen if we ran out of water? What's gonna happen if we can't clean water? 'Cause the kids don't understand that they turn on the tap and that's

> not a never-ending resource. And, um, we already started talking because we've been building solar cars for two years. We've already talked about the end of petroleum. When's the petroleum going to be done? It's going to be in in your lifetime. In 30 years from now, there won't be petroleum any more. What are we going to do?

Having students come to understand the workings of the world is what Delores wanted for her students. Yet, she noted how difficult it was to find a curriculum that would align with this and be appropriate for her students.

> The next step was to start looking at curriculum materials. Um, and that was very frustrating for me because we work in a very high functioning district. Um, we have high expectations for our kids. Even the old curriculum that we used is kind of a ninth-grade curriculum and trying to find something to fit middle school grades put out by publishers to fit our students, who are really functioning at a ninth grade level, I think for the most part is really hard.

It was difficult to find pre-packaged curriculums that met the intellectual needs of her students. Delores felt as though she had tried so many publishers without success.

> You can't go to a high school textbook for this grade, because it wouldn't fit. I tried. I read them. They didn't work. And then when you go to an eighth-grade textbook, it is really written for sixth through eighth grade, so it is really low. It really is.

The frustration she experienced in trying to find a new curriculum became clear as Delores spoke more about the limited published options. I asked if she might have felt better about creating her own curriculum, as it would be a better fit for her students. She said there was an expectation to find a published curriculum. Moreover, Delores wanted a published curriculum because it would come with literary and scientific resources for her students.

> Honestly I wanted something. Because I feel like we have so few resources like I mentioned before. We only have a hundred pages in this book. It's not enough for a year. We have no resources. There's nothing. There's not a website, there's not any SmartBoard stuff, there's one assessment book which is, you know, I can only use one-fourth of because we only cover a hundred pages in the book. So, I want to find resources for us.

Her criticism of the old curriculum was that it stagnated. She compared the 1970s version of the textbook to 2000 version and found little variation. Finding a new curriculum that came with updated resources was important to her.

Delores was not alone in her quest to seek out more up-to-date resources. She was also supported by the community education foundation. This foundation was dedicated to raising funds to buy new materials and supplies that were not within the district's budget.

> And one of the other pushes for our district, too, is to that, uh, they seek us out and say, 'what improvements can we make?' I've been sought out by the, um, foundation, which our foundation, education foundation, which gives grants to us to improve our science and right now they're at fifty-five thousand already for next year.

Delores felt this foundation supported her because they helped her department raise funds to purchase additional resources that are not included with the curriculum packages. She spoke excitedly about some of these resources she would receive for her energy unit.

> I'm planning on starting energy with solar cars before I even teach them about energy transfer or anything that's going to be like my hook to get them. And they love making the solar cars. They outrun the kids. They're so fast, the kits that I bought. So, that's good. Um, and then to end the unit I have purchased through the education foundation, um, they're miniature houses that the kids will build. And, you put a solar panel on it and a wind turbine and you can read how much energy is coming out of that and how much energy it needs, and the temperature in the house, and things like that.

Delores also secured these resources because she believed that the curriculum was still too teacher focused. As previously mentioned, Delores struggled with the idea of frequently lecturing her students. She wanted more engagement for them; she wanted more meaningful experiences.

> We're a little concerned. Our concern is that it's a little, um, teacher heavy. You know, I want it to be, I mean it's SEPUP. I feel like it should be inquiry-based. But, I don't feel like it is. Ha. I think that's interesting. It's supposed to be cutting edge. But, I don't know. But, um, so, when we went through the genetics unit we felt like it was

> really book heavy. Where's the experiment? Where's this, where's that? So over the last two years we've tried to pull in more experiments. And for energy, there are a lot of experiments. But, kind of you've seen how my classroom works: based on what I do it's very little tinker toy kind of things compared to what I do now. So we're going to have to improve it a lot. So, um, I think unfortunately the program is a little bit too teacher-based for me and we're going to have to turn it to a more lab-based, inquiry-based program for me. And for my colleagues. It's not just me.

I asked her to compare the materials she was seeking out to the materials that were included with the curriculum. She expressed some doubt and concern with the materials and activities that would come with the published curriculum.

> I don't know. Um, the solar cars and the power houses are not with the curriculum. Those are separate. Those are things that I said, we don't have enough, um, there's not enough in this curriculum to keep my kids busy, and to keep me happy as far as labs go. So the only thing I really know is for energy is some circuit stuff. And I hope that's even interesting to eighth graders. It's electricity—I feel like you learn that in fourth grade. I don't know. Um, light up a light, make a fan go. Really, that's what comes with this curriculum: it's frightening me.

Another challenge in finding the perfect curriculum was the solitariness that Delores experienced. As the most knowledgeable and experienced person in her grade-level, Delores was left to find curriculum materials on her own.

> Um, but the other thing that was so frustrating, I was a person—one person—trying to pick eighth grade curriculum for this district. And it's hard! And the two people who were in my department who I could go to and talk to hadn't sat through all of these meetings. They didn't see all these options that I saw. There were very few for what we wanted to teach. So, um, it was really a frustrating experience.

She clarified that her two colleagues are great co-workers but that their lack of experience made it difficult to consult with them and decide upon curriculum materials. Yet, there was a gap between when the curriculum was selected and when it was implemented. This gap was nearly three years. This time period had an impact on how the curriculum she selected was viewed by her colleagues.

> So now I, now I have teachers who I work with who are experienced. They've got five years' worth of teaching under their belt. And now they're looking at [the

> curriculum] and questioning, 'why did you pick this?' And I'm trying to backpedal and say, 'this is why I picked it. This was the best that we could find to meet our need. The best. And we are going to have to add to it.'

The New Curriculum

Delores experienced conflict in finding new curriculum kits for her grade level. Although the map reflected best practice and was aligned with the then-current National Science Education Standards, finding kits that matched the map and her beliefs on teaching science provided to be difficult. Ultimately, she found three kits she thought were the best available for her grade level. The primary reason being that the kits would connect to the students on a personal level. The curriculum would be meaningful to the students.

> So there's three units; they… so previous to the new curriculum, it was physical science for the entire year. Now with this new curriculum, one of the things that we wanted to do is tie it into real life, what kids would actually benefit from and can relate to, and also going forward in their life, and I'll come back to that. But … so our big units are water, there's a water studies, water quality unit. There is a genetics unit and then there's an energy, which focuses on first learning about energy and second learning about alternative energy sources.

The district laid out the map and major topics. It was up to Delores to find the kits that best matched the topics. She also wanted kits that matched her beliefs. I asked her to expand on how the kits she selected would help her students meet the goals of the curriculum map.

> What we want kids to get out of this is that, first we want them to have that citizen scientist piece, which we really get in the water studies. We also want them to be able to relate all of these topics to the real world, to real things that will go… that happen in their life. So I think that science itself sometimes is sep… like we separate these things out and then kids can't make those connections to the real world. So I think that by pulling these three units, we really succeeded with having kids connect with the world that they live in. So, for instance, water studies not only is it important to ecology and organisms but it's also really important to what comes out of the faucet. How does it get there?

> How do we know it's good? What kinds of things could be in there? And it's really relevant and current because we still are having cholera outbreaks, we're still having kids poisoned by lead out of water that's coming out of their thing, so … out of their faucets that's supposedly treated. So I mean it's really relevant, and current and kids are able to identify with that. Genetics, same thing; kids want to learn about themselves, they want to learn where they come from, they want to know why their eyes are blue and their parents are brown. They want to know how genetics works to create these kids. And they also want to know about the newer things, like hey can I have a clone to do my homework?
>
> That kind of stuff, you know. So, I hate to rain on their parade. And also that … we also take that genetics a little further and tie it into forensics, which is every day in the new, every day; we can talk about forensics every day. So, again tying that back to their world. And then energy, when we get to energy we give them a little bit of background, and then we go right into renewable energy. And the thing about renewable energy is that bringing to the attention to these students that we are going to run out of petroleum in their lifetime. So there has to be something else that we're going to do to create this energy that we depend on. So… and how do we use it? How does it get there? Where does it come from? Those kinds of things.

Delores made it clear that providing a curriculum that has life connections for the students was extremely important. Finding kits that did this was challenging. She wanted kits that provided life connection and were also inquiry-based. Many of the kits she found, including the ones that she adopted for her grade level, were still content focused.

> I think it's more content driven, I really do. I mean I think … I wish it was more problem … it's hard to make everything a problem. In every unit that we have, there are problems that kids are solving.

The challenge, she recognized, was getting the students prepared to solve these problems. For example, in the water studies unit, students had to solve problems related to local water ecosystems and water filtration. But getting the students to that point required addressing the content.

> Okay, so there are problems that kids are solving, so they're going to create their own water treatment system. They are going … and test it. They are going to go to a lagoon and test water quality and find out if it is a good quality or bad quality, so that's a problem to solve. They have to use evidence to prove whether or not the lagoon has good … is a good aquatic environment for organisms. They learn about things that they might find in their drinking water and they have to try to remove it.

> We use water filtration systems to remove nitrates from water. So yeah, so those are all problems to solve within the unit. But unfortunately it's based on like I have to get through this, they have to know about this water quality and that water quality for that.

She found the same challenge in teaching genetics to her students. Under the old curriculum, students had prior knowledge of DNA when coming into eighth grade. But with the new district curriculum map, students do not study genetics until they reach eighth grade. So, again, Delores found that she needed to provide enough background knowledge in order for the students to address problems connected to genetics.

> There's a lot of problem solving within it, but… Genetics a little bit less, I mean genetics you know you're talking about where the DN… first of all kids don't know where the DNA is, a lot of times. They do learn a little bit about it in seventh grade, but they still don't really have that tight sense of what DNA is and how that actually makes people inherit things from each other. And then… and so there's a lot of background that has to go into it, so that's content. The really… they get to explore maybe a genetic disorder, like what if you had that genetic disorder, would you want to know about it early in your life; or would… if it might come or it might not come. Mean they're kind of solving that problem. And then when they get to the forensics, they're solving crimes, I mean we teach them how to solve a crime using DNA evidence, and fingerprinting, and blood spatter and stuff, which we just add on.

I asked her to compare the amount of content taught in the new curriculum to what was taught under the old curriculum.

> So, it's definitely a lot more content because the old curriculum was only physical science. So, we stayed in physical science the whole time studying solutions, like temperatures, and densities and we were just kind of… there was… and there was no tie in to the real world. But yeah, no it… definitely a lot more content, a lot more to cover.

She felt the old curriculum had less content to cover because it was only one subject area. The new curriculum covered three subjects and, therefore, had more content to review in order for students to be prepared for problem solving. But, the old curriculum lacked the real world connection, which is of utmost importance to Delores.

I asked Delores to discuss the differences between how the content was given to the students under the old and new curricula. She expressed that the new curriculum had better ways for students to learn the content. The old curriculum was too teacher-oriented while the new curriculum provided various ways to engage the students.

> So, it's a combination of so many different things. I think that the way that we provide the material is varied because that's what's appropriate for our students. And it also, for me, makes the teaching a bit much more interesting. I would never lecture bell to bell. So, I would never do that, it's not appropriate for this age group. We have 13 and 14-year olds, attention spans are going to be about 14 minutes long, so I'm not doing that. So maybe they're doing an activity on… maybe I'm lecturing and they're doing an activity on iPads or maybe they're doing a lab, which is going to try to investigate this problem that I give them. So, it's always a combination of all different types of things.

The old curriculum was structured around lab experiences as well. Delores noted that while the old curriculum did have labs, they were not necessarily inquiry-oriented. The labs demonstrated to the students what the textbook dictated as correct. The labs validated the textbook for the students. She found the same frustration in the new curriculum. The labs were serving the same purpose as in the old curriculum.

> The way I teach the new curriculum is more inquiry-oriented. It's interesting that the curriculum itself calls itself inquiry, because if you read any of the labs that they have in their book, I don't know how that's allowed to be called inquiry because it's not. It is a recipe, you know here… and we know that's not inquiry, they don't se… and even if they try to set it up within this curriculum as an inquiry-based, the answer is always on the next page. So, I stopped using the book, I started… if there's anything that I'm trying to let them figure out on their own, we would type it out and have it outside of the book, because the answers were on the next page or the page after. Oh now that you've done… found that the pH is seven, and that's neutral, then… so it would always… it was so frustrating to me, I'm like oh my gosh even when you try to be inquiry-based, you're not doing a good job.

Modifying the kits was a necessity for Delores. After teaching with the kits for a year, she recognized that the texts were not meeting the needs of her students nor were they as aligned with inquiry learning as she thought. So, she set aside the books. She no longer used them in her classrooms. But, this is not to say she does not use the kits anymore. She just found that the sequence is not appropriate for her students.

> We do not follow it closely at all. What we did the first year, the very first time we used the genetics, we followed it and we saw… and then we chose out of there… the problem with the curriculum is that it's written for sixth through eighth grade. And I teach high level eighth graders, so some of the stuff is just too babyish, it's just is, it's not an appropriate level for an eighth-grade student getting ready for high school, particularly this district. We have really high standards here, and so if you're using a book that a sixth grader could also be using, yeah it's not enough, there's no challenge there for our students. So you know what we did, we just pulled out things that we really, really like and we follow that part of it.
>
> And it's not that we're not using the curriculum at all, it's just the fact that we've just kind of… we might've rearranged it, we might be using seven of the inquiry things instead of ten of them, that's pretty much it.

Although she and her fellow eighth grade teachers rearranged the kits to fit their students' needs, they did not contradict the district's curriculum map. The district offered the opportunity to review and revise the map after the first year teaching the new curriculum.

> We are following the map really, really well, but we are able to revamp the map. Once we did the curriculum for a year or two we were able to revamp the map. And then so… I mean like anybody could pull that map out and come over here and look at it and say, "Oh they're doing great."

The first year teaching the new curriculum was an overwhelming experience. Delores commented on how time consuming it was to learn the material, grade students work, and find ways to make the curriculum fit her students' needs.

> I was a wreck; it is so hard to take on a new thing and like here's the thing, I mean I have really been teaching for 20 years and I used to teach genetics. Well we still use some of those great genetics things that I used to do, but genetics has changed in this last 20 years, oh my gosh. So you have to stay up to date, you have to study, you have to read and it's so time consuming starting a new curriculum because there's so much … They have like for instance, in the first unit they have this thing on water quality, which is called mapping death, and I love, love, love it. It's about the cholera outbreak in London and you never tell the kids. So this is actually an inquiry thing.

> You don't tell the kids, well if they had the book, they would know because the next page says cholera. So, we had to take it out of the book, so that they wouldn't see it.
>
> You have your own amount of homework plus you have to grade everything, plus you have to say that did not work at all, so sometimes you're redoing it the next day. Or that was … that activity did not show the point. I can give you another example which is PPM, parts per million, their parts per million lab was awful. It was, yes kids should know what parts per million are, when we're talking about water quality, for sure. But the way they had us do it, it didn't show parts per million, it showed little drops in a cup. And I think that's the biggest problem with the kits, is that they're trying to make it so that you can afford the kits. And so everything is so miniscule, that you don't … it's not a real lab.
>
> So, one of my teachers, that I work with, used to be a biochemist and she goes, "You know how you do parts per million? Get them out some test tubes, I'll show you how to do parts per million." And then now we do the parts per million lab that they have, but we use test tubes and it's so much better, the kids get it completely. Where before when we were doing like 10 drops and one drop in little cups, they weren't getting it.

Delores felt better after her first year teaching the new curriculum. Once she was familiar with the curriculum, it was not as much of a burden to prepare for the upcoming lessons. She also found that once her basic materials were in place (e.g. slides and labs) it was easier to keep the curriculum up to date with recent events. For example, she discussed how E. Coli was an issue with water in the community where she teaches.

> And then I'm tying it in with E. coli because kids hear about E. Coli a lot, that's in the news a lot, so I'm tying that bacterial contaminant with that. So yeah, yeah it's definitely a lot easier. And the cool thing is, is that now you can take what you already learned and you can put in more up to date stuff.
>
> And then there was the hurricane recently and they were having a cholera outbreak in Haiti and so we were talking about that again. So, again bringing in that whole global perspective, talking about drinking water and making sure it's safe for third world countries

Delores never settled with the curriculum. As change is an important value to her identity as a scientist, she commented that she will always be reflecting on the curriculum and making changes to it.

> I can't believe how hard I'm still working. I just don't think I'm ever satisfied. I think that every time, and I'm not trying to make myself sound good, but I just… oh yeah last year… I mean I keep lesson plan books still, I'm still old school, I'm still on pencil and paper and then as soon as that week is over, I write down what I didn't like almost every week you can see something that I didn't like. Or I'll write this was really great right here, this was a great day to do this. Or this lesson; I loved this part of it. So it never… it never is the same.

She shared an example of how she accomplished this with a field trip she and her students take to a local water ecosystem. They team up with scientists who study the area and the students learn about the ecosystem and study as scientists do. She discussed how the field trip has changed every year.

> We used to just have a nature walk and a water quality chemistry testing. This year we added a third grouping and it … we had to change everything in order for that to work. Where we were capturing microorganisms, macroinvertebrates from the lagoon and then doing actual, from the Chicago river people, an actual pollution tolerance index, based on that. So, I mean we got to use paperwork that real scientists use and we did it with real scientists. I mean seriously that is pretty fricking awesome.

She's also done the same for a water treatment project the students complete. In the first years of the curriculum, Delores had her students design a water filtration system. Now, however, it is placed within context of a zombie invasion. Although it may sound silly, Delores wanted the students to know how to purify water when they don't have access to their normal utilities (e.g. electricity). The zombie component just made it more fun for her students.

> Last year we built water purification systems and all the same teachers in… the newer teachers in our department built their water filtration systems with their kids, but I didn't. I had water that was infected by zombies and my kids had to learn how to filter zombie water.
>
> And they came into a new challenge every day, so my kids had even more buy-in, because I took our curriculum which is build a water filtration system for storm water, to build a water filtration system for zombie water, which is exactly the same chemistry as the storm water, but way more fun. Kids were coming in, they couldn't wait, one day we lost power, pretend we lost power, we did… they had to do all their

> experiments by fire …by fire, by flashlight. Another day if a zombie entered the room, they had to take cover. I mean it was just really, really fun and cool and it was just something that was added to something that was already in our curriculum, already there, but kids really cared about it.

Not all of the changes made to the new curriculum were done solely within the classroom. Two years after the adoption of the new curriculum the district requested all the seventh and eighth grade science teachers in Delores' school meet to align the new curriculum to NGSS. She found that this task was not as difficult as imagined. However, Delores and her colleagues found that the curriculum was not NGSS aligned as much as they had thought it was.

> We revamped our curriculum after doing this for a year or two, we actually got back together again, looked at NGSS, again, compared it again to see if we were close. And my partner, at the time, Laura, was really good at it and she actually was able to find a couple of places where we still weren't meeting it, even with the new curriculum. Because I think curriculum say they're aligned, but they really aren't. I don't really think that… I haven't found that there's one curriculum where you can just grab it and go.

Once again, Delores found herself making modifications to the curriculum. She added an ecology component in the water studies unit. In her genetics curriculum, she added a forensics unit as she thought the NGSS standards were lacking for genetics.

Delores saw the value in NGSS. She believed many school districts needed it as a push to teach science through inquiry. She wondered how other districts would handle NGSS. She wondered if the standards will be too challenging for them.

> I actually think NGSS is probably a good thing. I think that there is a lot of people who are really slack… For us in this district, I don't think we needed NGSS. I think for other districts, that don't focus on science, I think they need NGSS, they need to know that kids need to be challenged or we're never going to have those scientists later on in life that we need to be coming up with all of our ideas.
>
> That's what I think about it. And now, you know you're thinking about it, like I want this to be so good and I want them to get this. I mean they're challenging, I don't know that all schools can get through those NGSS standards, they're challenging.

> And I think people don't have time to do all of those sometimes, I mean they're so time consuming.

Summary of Delores' Findings

Delores has a strong identity as a scientist. She connected to science at an early age because it was meaningful to her. She saw purpose in it and recognized the value it contained. As such, she values change and professional development. Science frequently undergoes change and professional development is a way for her to continue experiencing change within her discipline.

The old science curriculum Delores taught did not reflect these values. The curriculum had not been updated in the 30 years it had been taught in the district. It was very teacher-oriented, did not include much change between versions, and the students found little meaning in the curriculum.

Consequently, finding a curriculum that reflected these values was important to Delores. However, it was difficult to find a packaged curriculum kit that contained these values. Eventually, she settled on three curriculum kits and modified them to fit with her values and the needs of her students. She continued to update the curriculum each year that she taught it.

Chapter 5:

Discussion and Implications

The purpose of this phenomenological dissertation was to understand the experiences of veteran science teachers in adopting new inquiry-based science curriculum. The four teachers in this study were recruited from my network of professional contacts. These science teachers have each taught science for a varying number of years. Although their background in teaching science is different, each has a strong knowledge of science content and pedagogy making them well suited for teaching science.

Each participant had taught a traditional—teacher lead, direct instruction model—science curriculum prior to teaching with the new inquiry-based science curriculum kits. This dissertation was designed to learn what their experiences were in this transition. The use of phenomenological methods allowed for a focus on the participants' understanding of their experience. This is beneficial as how each person experiences a phenomenon is different based on their prior life experiences. Thus, while each experiences the same phenomenon, how they experience it is different. This dissertation was designed to understand those differences and come to know the essence of their experiences.

In this chapter I will answer the two research questions presented in chapter 1. Answering these questions was done after reading the interview transcripts and analyzing the findings from chapter 4. In this chapter, I provide an analytical diagram that illustrates the themes of their experiences and explain how those themes interact to better understand the experiences these teachers had. Finally, recommendations and limitations are discussed.

Research Question 1

The first research question addressed the experience of the science teachers and the new inquiry-based curriculum. The first research question and its sub-question asked:

1. How do science teachers experience the implementation of a new inquiry-based science curriculum?
    a. How do their beliefs of and values in science education contribute to their implementation of a new inquiry-based science curriculum?

Each of the co-researchers experienced the implementation of the new curriculum in a different way. This is due to several factors. First, each teacher has a unique background that contributes to their experience. Their backgrounds contribute to their understanding of how to enact an inquiry-based curriculum. Second, each teacher has beliefs and values that are important to them in teaching science. These are heavily rooted in their backgrounds as those shaped each teacher. Third, each teacher received different kits to teach. Although Delores and Laura taught using the same kit, their backgrounds and beliefs varied their experience in teaching with the new kits.

The following section is broken down by teacher and provides a summary of their experiences in implementing the new kits in their classrooms.

Judy

While Judy experienced change in how she taught while implementing the new curriculum, her beliefs and values remained consistent. Her beliefs and values are founded in her experiences as a student. In elementary school, she particularly enjoyed science as it provided a challenge for her. Judy commented on how science in seventh and eighth grade made her think differently than the other subjects did. She enjoyed that science was an open exploration of the world; science encouraged question-asking and not accepting information at face value. She appreciated the critical thinking skills that science so acceptingly employs.

Judy's experiences as a student, though, were not always positive. She shared how many of her teacher education courses were restricting. The classes didn't teach her how to be a good science teacher. Instead, they taught her what not to do based on how the professors led the courses. Additionally, the classes did not challenge her. Judy felt constrained by project requirements. She also found the lack of the professor's interests in the students to be unsettling. In her undergraduate program, Judy felt the professors were there for their own reasons and not for developing her into a model science teacher. Similarly, in her post-undergraduate online chemistry class, she found the professor dismissive of students when they had questions and left it up to them to obtain help outside of the virtual classroom.

Having lived through those experiences, Judy believed challenging and responding to her students to be an important value in teaching science. She did not want to constrain her students. Judy wanted to push them to whatever level they can reach.

Judy found that this was not easily done with the material available in the old curriculum. She spent hours searching for supplemental materials that allowed her to meet the needs of her students. She also found that the structure of the text was not engaging and focused too much on content. There were few opportunities for labs or investigations. The engaging moments for the students were found in teacher-led demonstrations. Thus, she modified the curriculum and made packets of materials for her students. Judy also made entertaining her students a priority so learning science was more exciting than simply reading a textbook.

As Judy transitioned to the new curriculum, Judy found that her previous style of teaching as an entertainer was not necessary. The new curriculum was naturally engaging for the students. It provided investigatory opportunities and asked guiding questions that the students worked towards answering. Students found answers to those questions through inquiry practices. There were many pathways to finding the answer.

Judy found that her new role as a teacher would be a questioner and guide rather than an entertaining leader. She no longer had to put on a show. Rather, she had to guide the students through the process of working toward an answer to each lesson's guiding question. Judy found this was a better fit for her beliefs and values in teaching science.

As students could take their own path to finding the answer, Judy learned that each student could be individually challenged. Lower level students could take a route that would be more simplistic in answering the question. Higher level students could reach the same answer in a more complex manner and have opportunities for extending their work through inquiry learning.

Although Judy felt a better fit with the new curriculum as a teacher, she found that the curriculum format did not always work for her students. She felt that the open investigations would benefit from a greater introduction of background knowledge. Judy felt students could connect better with the investigations if they knew more about what they were experiencing.

Judy was not satisfied with how SEPUP required students to do so much documenting prior to the investigations. She discussed how at the lessons' beginning there could be up to 20 minutes of copying information over into the science notebooks. But, she found the general structure of the SEPUP lessons to be beneficial for student learning. When Judy moved from fifth to sixth grade she had to learn a new science curriculum. The new curriculum was provided by STC. Judy felt that the flow of the lessons was better in STC but found a lack of a central guiding question in each lesson to be a downside to the kits. As she had done with SEPUP in fifth grade, Judy made modifications to the STC curriculum. This time, however, she combined her favorite aspects of SEPUP with her favorite aspects of STC.

In modifying the curriculum, Judy ensured that her beliefs and values in teaching science were met. Her beliefs and values seemed to be concomitant with the scientific practices found in the curriculum. The inquiry kits were structured in a way that allowed her to challenge her students, allowed her students to leave with an increased understanding, and allowed her students to develop their extracurricular skills (e.g. social and self-reflection).

Judy's experience was one of restructuring and re-navigation. As she learned the new curriculum, she had to restructure it so her beliefs and values were found in it. Although many aspects of her beliefs and values were in the curriculum, she found that some areas were lacking. Judy had to reinvent herself due to the nature of inquiry in the new curriculum. It was no longer necessary for her to put on a show for her students. Judy had to change her role as a leader to that of a guide to help her students navigate the new curriculum.

Elizabeth

Elizabeth's philosophy of learning science was captured in one word: fun. To Elizabeth, science was naturally fun. She connected fun with the phrase *hands-on* although she clarified just because something was hands on does not mean it was also fun.

Elizabeth believed that learning science is more than just learning its content, as the content will always be there. Students could easily access it through the plethora of available resources. Elizabeth described learning content as a snooze fest. She did not find focusing on content engaging for herself or her students. The old curriculum focused heavily on content as the basis of the curriculum, a traditional textbook, was the starting point for every lesson.

As a result, Elizabeth tried to make the content in the old curriculum more exciting and fun for the students. She made review games and activities that would have the students moving around the room. Although she made it fun for the students, Elizabeth found the curriculum lacked meaning for the students. Throughout the interviews, she would reference content and activities that the students struggled connecting to.

Elizabeth modified the old curriculum as best she could to make it more meaningful for the students. In the geology unit, students focused on landforms as Elizabeth believed that would be better than learning the nuances of rocks and minerals. By studying landforms, she hoped the students would have a greater appreciation for the systems that exist on and within our planet. Elizabeth wanted them to see how cool our planet is so they'd have a greater respect for it.

Developing this sense of wonder was another component of Elizabeth's beliefs in teaching science. If she could develop their sense of wonder then, perhaps, her students would become more curious about the world. The old curriculum was not allowing her to do this because it was focused on content. How can her students be curious about the world when they learn science as a body of facts? Would it be better to teach the students how to go out and learn new information on their own?

Elizabeth believed that science is a body of skills that students must learn. In doing so, they develop a greater appreciation of their world, a sense of wonder and curiosity, and can genuinely learn new information rather than just look it up. Elizabeth recognized that students could learn important skills through science: problem solving, arguing, and working collaboratively. But this could not be done through a content-based curriculum.

The new curriculum presented an opportunity for Elizabeth to enact her beliefs in teaching science. The new inquiry-based kits she received aligned well with her beliefs. She was glad that content took a backseat in the new kits. The focus was learning how science was done and content was learned along the way. For example, in learning how to collect data on a living organism, students learned the anatomy of the organisms. More importantly, however, they learned data collection techniques and experienced messy data. Accompanied with that was discussions on how to analyze messy data.

Elizabeth encountered struggles with the new curriculum. She felt her creativity was stifled as the new curriculum was more prescribed than the old curriculum. In the old curriculum, she had more choice of how to present information, as it was so content driven. With the new curriculum, however, the sequence of lessons and steps within the lessons were more structured to ensure students were learning through inquiry.

Elizabeth also found time was a constraint on her teaching. Much as Judy struggled with the short class periods, Elizabeth, too, wished that she could have a larger block of time. She found it difficult for the students to learn scientific processes when they were fragmented over several days. She felt there were few chances for meaningful conversations with the students as she only has 40-minute days with them.

Elizabeth also realized there was a pressure from outside the classroom that took away the fun and meaning she wanted in the curriculum. Elizabeth felt she had an obligation to parents and future teachers to make sure her students knew how to process a non-fiction text, take notes, and study for an exam. Again, Elizabeth knew these were important skills to learn. But, she found they take away from the learning experience she wanted for her students since those skills focused on the content. Elizabeth would rather spend that time doing more inquiries and extending her lessons with further questions for exploration.

Elizabeth's experience became a balancing act between her beliefs and values in teaching science and the pressures from outside the classroom. She wanted to develop her students' sense of wonder and appreciation for the world but also recognized she needed to develop her students' other academic skills.

Laura

Laura felt trapped by the old curriculum. The old curriculum was textbook and lab driven. The topics were limited to only physical science. The curriculum followed a format of pre-lab, lab, and post-lab. The pre-lab and post-lab were typically whole class instruction and teacher directed. These were incongruent with what she had learned in her teacher education program. They also conflicted with her beliefs on what science should be used for. Science should not simply be a body of knowledge but a discipline that prepares students for future careers and general problem solving.

Laura tried to make changes to the old curriculum but found she was constrained in doing so. The old curriculum was so broad in its scope and sequence. When she attempted to make changes, she found it threw off the pacing. Her students completed a project at the end of the year that was based on all the year's lessons. She had to keep up with the lesson pacing for her students to be ready for the final project.

This is not to say that all aspects of the old curriculum were negative. Laura found the lab and data analysis experiences beneficial for the students. Even so, these experiences did not reflect how scientists worked in the real world. Students were not asking their own questions, they were not developing methods to answer those questions, they were not reflecting on their work, and they were not refining their practice. Instead, the students followed a cookbook recipe and hoped the outcomes they reached were the same as the expected outcomes contained in the teacher's book. Consequently, Laura found the curriculum lacked meaning for the students. Studying mass, volume, and other physical properties of matter were not relevant for her students.

Laura was excited with the adoption of the new curriculum. She found her role as a teacher changed from being the holder of information to a guide for the students. Laura was glad her students had a new role, too. Her students no longer worked towards finding the right answer. Rather, they mimicked what scientists did in the real world. They would openly explore topics in order to develop pursuable questions. The students had to find ways to answer those questions, reflect on their findings, and figure out what to do next.

The textbook that accompanied the curriculum was low on content and put a focus on the process of how science is done.

Although the new curriculum was aligned with Laura's beliefs, she found there were still some things to be desired. She felt the general topics were too simplistic for her students and they needed something more challenging. Laura felt there were times where the content was too specific and didn't address some of the larger ideas she wanted the students to learn. In response, Laura modified the curriculum to make it more aligned with these beliefs.

The changes Laura made included addressing broader concepts (e.g. structure and function). She brought in aspects of the students' local community to make the learning more relevant for her students. Laura and her colleagues brought in additional resources to fill in what they felt were gaps in the curriculum. She and her colleagues also aligned the curriculum to NGSS, which presented more opportunities to revise the curriculum.

Delores

Delores struggled for years to make the old curriculum align with what she believed. The old curriculum did not offer students meaningful experiences. The focus on physical science was not engaging for the students. While she made changes to the old curriculum, the other teachers in Delores' department did not support her. She knew they would not change their teaching practices as they had been teaching the old curriculum for over two decades.

To remedy this issue, Delores sought outside professional development. It was through professional development that Delores saw ways she could make changes to the old curriculum. She implemented changes in her curriculum and felt it was becoming a better fit for her and her students. Delores wanted the students to learn science in a way that would personally connect with them. And she found the changes were helping her do that.

When the district planned to design the framework for the new curriculum, Delores applied to and was accepted to the review committee. The consultant that was hired was knowledgeable in best practices and was familiar with the upcoming NGSS. Thus, she was supported in the changes she wanted to make. The result was a curriculum map that reflected Delores' beliefs and values in teaching science. She now had the task of finding curricular packages that matched the map.

She struggled in finding a new curriculum that matched her beliefs. She found the inquiry kits were either too simple or challenging for her students. She eventually settled on what she felt was a best fit for her and her students. As she taught the new curriculum, Delores began modifying it so it became a better fit. She eventually got to a point where she no longer used to the textbook because it did not reflect her idea of inquiry.

But this reflected what Delores believed was important in science and to herself: change. Science as a discipline changed with new discoveries and theories were updated to include new evidence. Further, Delores never settled for achievement; she does not want her students to just meet a benchmark or standard. She believed in personal growth: her students should grow beyond their initial understanding of the topics she taught. Therefore, it is not surprising that Delores made many changes to the new curriculum.

Delores reflected on what she taught under the new curriculum, which was consistent with her belief in accepting that change is part of her profession and discipline.

Delores stated she never wanted to be the teacher who worked out of a folder. She kept notes on what she believed worked well and what did not work well with her lessons. She routinely modified her work in order to improve it.

Delores accomplished this, in part, by making personal and relevant connections for her students. Her water studies unit culminated in a field trip to a local riparian ecosystem. She also tied in natural disasters that included water treatment as a concern. For example, a cholera outbreak in Haiti made learning exciting as her students wanted to problem solve: how do you filter water when there are limited resources?

Designing and implementing the new curriculum was a process of liberation for Delores. She was no longer constrained by her former colleagues and could instill her values and beliefs into the curriculum map.

Research Question 2

Having established the experiences of the teachers in implementing new science inquiry-curricula it is possible to answer the second research question. The second question is: What are the essences of their experiences? In other words, what is the experience of implementing the new curriculum such that I can now better understand what this experience is like for other teachers? Examining the crosscutting themes that emerged in analyzing the data answers this question. These themes are: feeling trapped, finding a fit, making a meaningful experience, and finding balance.

Feeling Trapped

Each of the teachers had experienced a feeling of being trapped by the old curriculum. They were unable to provide an inquiry-based experience for their students. This was the result of the old curriculums' focus on content and not on scientific practice. Consequently, the teachers all made modifications to the old curriculum to make it more inquiry oriented, thus aligning it with their beliefs. However, the teachers encountered struggles in doing so. These struggles included balancing content with skills, finding topics that were meaningful for the students, constraints of a 40-minute class period, and the curriculums' fast pace.

When the teachers received the new curriculum, they were excited it was inquiry-based and aligned with how they believed science should be taught and learned. They tried to faithfully implement it as written but found it was still not a perfect fit for their students. Because of this, the teachers began making changes to the curriculum.

Finding a Fit

Each of the teachers had modified the old curriculum to fit their beliefs and values in teaching and learning science. They similarly did the same when the new curriculum was implemented. The teachers were excited to use the kits as they were inquiry-based and were more aligned with their visions of how science should be taught. However, as they used the kits they found that they did not fit perfectly with their beliefs and did not meet all the needs of their students. Therefore, they made changes to the kits that they felt were appropriate.

Judy replaced the textbook with packets that she created in the old curriculum. She used an abundance of resources to help her create packets that met the needs of her students. For some students, this meant receiving packets that made the ideas more accessible or extended the ideas beyond what was required by the school district. It also affected how Judy taught. She was an entertainer with the old curriculum. She wanted to bring it to life. With the new curriculum Judy found a better fit but still made changes so her beliefs were present in the curriculum. She modified the structure of the lessons to incorporate her favorite aspects of two different curricula kits.

Elizabeth strived to make learning fun for her students. This meant reducing the focus in content in the old curriculum and including more games and physical activities. She also felt that the content was too narrow and missed larger, more important concepts. Elizabeth found a better fit for her values and beliefs in the new curriculum. She, too, had to modify the new curriculum to ensure that her values and beliefs were present. She eliminated lessons that she felt were not aligned with what she believed was important in teaching science. These included lessons that were too content-focused, did not allow students to engage their curiosity, and did not increase the students' appreciation nor give them a sense of responsibility for their world.

Laura found the old curriculum to be too content-focused. Due to its large scope and sequence, special attention had to be paid to pacing the lessons. This did not leave much room for her to make modifications and she found herself trapped under an outdated style of teaching. The new curriculum provided more options for differentiation, which was in line with what Laura believed to be important. She pulled in more local contexts for the students so they could see the meaning in what they were learning.

Delores aspired to remove the old curriculum from the school and replace it with a new curriculum that was inquiry focused. As a committee member in charge of selecting the curriculum for eighth grade, Delores struggled to find a kit that matched the needs of her students and what she believed was important in teaching science. The kits she did select were soon modified to fit her beliefs. She no longer used the textbook and made changes to her lessons each year to keep them up to date and meaningful for her students.

Making a Meaningful Experience

Each teacher had indicated grander purposes for teaching science and incorporated those purposes into the curriculum. The inquiry curricula seemed to naturally allow this to happen. Judy wanted her students to become problem finders and problem solvers. Elizabeth wanted her students to have a sense of wonder so they can have a greater appreciation for the world they live in. Laura aspired to equip her students with necessary skills that will help them in future careers and problem solving. Delores similarly wanted her students to be equipped to handle future problems (e.g. loss of fossil fuel resources and ensuring access to clean drinking water).

Finding Balance

Each teacher found that modification to the curriculum was accompanied with a need to further find balance. While the teachers molded the curriculum to fit their values and beliefs, they had to ensure that the curriculum still addressed other components of learning. This was very evident with Judy and Elizabeth. Both teachers struggled in balancing scientific practices with scientific content. Both teachers wanted the focus to be on the scientific practices but the content was the means through which the practices were addressed. Yet, in evaluating the students, both Judy and Elizabeth could lose sight of the practices and hone in the students' use of grammar, spelling, writing styles, misconceptions, and content.

In an e-mail follow up interview, Delores shared a copy of a report published by the district. The report surveyed the previous year's freshmen on how prepared they felt for each of the content areas in their first year of high school. The report stated that only 57% students felt prepared for high school science classes. This contrasts with the over 80% of students reporting they felt prepared when they learned science with the old, traditional curriculum. This was concerning to Delores as she felt the new curriculum is what the students needed.

The report discussed how Delores had followed up with the high school and found that their curriculum followed a traditional teacher-directed style blended with inquiry opportunities. This seemingly explained why students in prior years had felt more prepared. However, she and Laura felt that they must balance their desire to teach through inquiry with traditional skills they thought were no longer necessary. These traditional skills include preparing for traditional assessments, processing non-fiction texts, and being able to take notes from lectures.

Analysis of Themes

The four themes do not stand alone. That is, the themes work together to reveal the essences of the teachers' experience with implementing the new inquiry-based curriculum. Figure 5.1 demonstrates this as an analytical diagram.

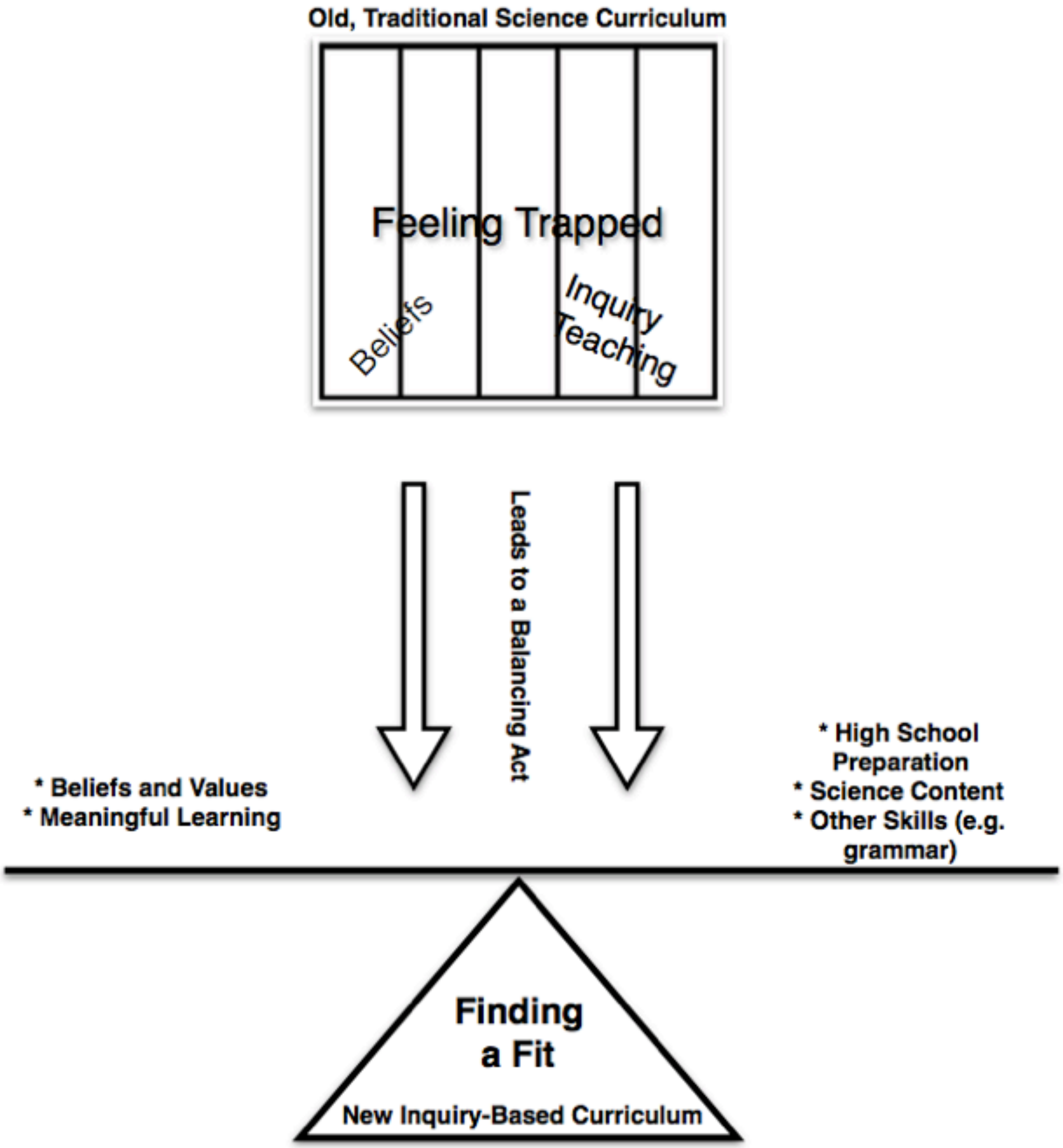

Figure 5.1. Analytical diagram of themes.

The diagram shows how the themes interact with each other to provide an understanding of the teachers' experiences. First, the teachers felt trapped by the old, traditional science curriculum. Its focus on science content over practice did not align with the teachers' beliefs of the purposes of science nor did it align with their beliefs of how science should be taught through inquiry. The diagram visualizes this with a jail cell: the bars represent the old curriculum preventing the teachers from teaching science as they believe it should be taught. While the changes they made to the curriculum provided some relief for their values and beliefs, it did not affect the fact their curriculum was grounded in a non-inquiry framework.

The new inquiry-based kits, however, provided an opportunity for the teachers to embed their values and beliefs into the new curriculum. This led the teachers to find a fit through achieving a balance by changing the new curriculum. These changes included adding and removing lessons, eliminating the textbook, bringing in additional resources, connecting the learning experience to local ecosystems and global problems, and focusing on the processes more so than the content. However, this all lead to finding a sense of balance for the teachers. The teachers had to balance their beliefs and values of science education with other aspects of the curriculum. For example, their former students feel more unprepared for high school classes. The teachers felt responsible for addressing other content areas by working with students on their reading and writing skills. This meant the teachers had to focus on content to prepare the students for high school and ensure they were helping the students improve their reading and writing skills.

Examining the four themes uncovered the essence of these teachers' experience: freedom and reconciliation. The idea of freedom is experienced in the transition from the old, traditional curriculum to the new, inquiry-based curriculum. The teachers experienced freedom as their beliefs were no longer trapped by the old curriculum's framework. The teachers now had the liberty to fully teach through their held beliefs. However, this liberty was not without limitation. The teachers were still required to meet the goals of other reform efforts, such as Common Core, expectations of being prepared for high school science, and their own negatively held views on aspects of teaching and learning science (e.g. content) that are found in both the old and new curricula. Thus, the teachers had to reconcile their teaching with these sources of limitation.

Implications

This dissertation has shown that phenomenological methods are able to reveal science teachers' values and beliefs in teaching science. Examining these values and beliefs in conjunction with their experiences of the curriculum allowed for the development of the analytical diagram presented earlier. This diagram visualized the relationship science teachers have with their curriculum and how they experienced the transition from a traditional curriculum to an inquiry-based curriculum.

The presented analytical diagram also showed how the four science teachers' values and beliefs interacted with the old and new curricula. The diagram showed that the new inquiry-based curricula provided a better although not perfect fit for their values and beliefs. This leaves the teachers with a balancing act of incorporating what they and others feel is important in their classrooms. If this balance is shifted away from the philosophy of the new curricula (e.g. the teachers begin focusing on content rather than process), then the success of the new inquiry-based curriculum is in jeopardy. However, the changes they made to the kits did not undermine the kits' philosophies. Rather, the changes they made were done to ensure their values and beliefs were in the curriculum kits.

Both Laura and Delores taught three SEPUP units. The SEPUP units are issue oriented. SEPUP's (2009) issue oriented curriculum has three goals:

1. Engage students in scientific learning,
2. Have students use scientific evidence to make decisions, and
3. Educate students on the application of scientific knowledge to everyday life.

While neither Laura nor Delores consistently taught their SEPUP curriculum as written by the publisher, the changes they made to the curriculum appeared aligned with the goals of issue-oriented science. Delores spoke at length about making the curriculum more meaningful for her students by bringing in local connections. She also discussed how she would connect disasters to what the students were learning. She redesigned the investigations to reflect what she believes are future problems for the students (e.g. access to clean water and renewable energy solutions).

Judy and Elizabeth teach using the STC Secondary curriculum. The Smithsonian Institution (2013)—the developers of the STC program—noted two goals with their curriculum packages. First, they want to provide students with standards-aligned curricula (i.e. the National Science Education Standards prior to the release of NGSS). Second, they want students to engage in authentic scientific practices such that they can develop scientific knowledge and attitudes that will prepare them for STEM careers and make them scientifically literate. Judy and Elizabeth's modifications to the curriculum do not seem to violate these goals. Instead, their changes seem to provide for students meeting the goals of the STC program. Both Judy and Elizabeth focus heavily on scientific practices in their classroom and work to instill a sense of awe and wonder in their students. In addition, they work to ensure their students are learning skills that will be necessary in their future careers.

The changes the teachers made to the new curriculum were meant to ensure their values and beliefs were represented. However, the teachers experienced a balancing act as they struggled to reconcile components of the old traditional and new inquiry-based curricula. Content was a central component of the traditional curriculum. Each of the teachers had modified the old curriculum to decentralize the content in order to give priority to their beliefs of what is important in teaching and learning science. They had to reconcile this former decentralized role with how content is situated within the new curriculum. Thus, they questioned how to integrate content into their instruction. For example, Judy asked if she should teach students certain vocabulary terms prior to inquiries in order to help guide students through the learning process. Similarly, she wondered how much content is needed to understand the brain as a component of the body's nervous system. As another example, Elizabeth questioned how much to focus on content as it is so easily available from in-class and online resources.

Both Judy and Elizabeth had questions about how to grade their students. Both want to focus on grading the students' understanding and demonstration of scientific practices. However, they find themselves getting lost in other aspects of writing: grammar, spelling, punctuation, and citations. This slows down their grading process and leads to frustration. They are struggling on how to assess their students' scientific practices. These science teachers need guidance in how to address these aspects of the curriculum that they are questioning or attempting to reconcile with their beliefs.

The analytical diagram provides a way to help the teachers accomplish this reconciliation. The diagram visualizes what future, ongoing, transformative professional development is needed to ensure the success of the new curricula. For example, the diagram shows that the teachers felt trapped by the old curriculum. Understanding why they felt trapped in the old curriculum and what they did to find relief revealed their values and beliefs in teaching science. Administrators and curriculum specialists can look at this information to predict what might happen with a new curriculum. From these predictions, they could provide professional development that would help reify the teachers' reform-aligned beliefs or provide them opportunities to expand upon them.

After the transition had occurred, the findings revealed the teachers in a balancing act. On one side of the balance are what the teachers' find important in teaching their students science. On the other side is what the teachers feel is taking away from what they want their students to experience. For example, the teachers are being told their students do not feel prepared for high school science. The teachers are now integrating practices in their classroom (e.g. lecture and traditional assessments) that they feel are counter to their beliefs. These teachers' administrators or curriculum specialists could design or find professional development that would help them resolve this conflict.

This analytical diagram could also serve as a way to analyze other teachers' values and beliefs in the context of a transition from a traditional to inquiry-based curriculum. Although this study is not meant to be generalizable due to its phenomenological methodology, the diagram presented can serve as a skeleton for analyzing teachers' values and beliefs. For example, interviewing other science teachers with different backgrounds could reveal the relationship their values and beliefs have with a traditional curriculum and how those would fit within the philosophy of an inquiry-based curriculum. This could provide guidance towards targeted professional development needed to ensure the success of the new inquiry-based curriculum.

Recommendations

Academic research has shown that teachers will modify curriculum to fit their values and beliefs (Keys & Brian, 2001; Crawford, 2014). However, if the values and beliefs are incongruent with the curriculum, this could be detrimental to the successful implementation of the curriculum's philosophy. Yet, this dissertation has shown that even when the teachers' beliefs are aligned with the curriculum philosophy, they will still make changes to ensure a better fit with their beliefs and students' needs. However, they struggle to find a perfect fit. They also had uncertainty in grading and the role of content due to their prior experiences with a traditional curriculum.

Cronin-Jones (1991) argued that teachers are going to make changes to the curriculum; administrators and curriculum designers cannot expect a curriculum to be implemented without change. Cronin-Jones (1991) further argued that curriculum developers take additional steps to better understand teachers' beliefs about science education. A survey of beliefs could allow the developers to integrate these beliefs into their curriculum design process. This dissertation extends Cronin-Jones' (1991) recommendation by proposing curriculum developers build flexibility with the lessons; give teachers options on how to meet the philosophy of the curriculum rather than having rigid lessons with little flexibility. The SEPUP materials used by Judy, Delores, and Laura included a statement to the teachers telling them not make modifications to the lessons their first time through in order to know how the lessons are structured. The publishers seemed to recognize teachers will make changes in order to accommodate the needs to the students and the teachers' beliefs. Yet, Judy received a message counter to this when she went through training on the kits.

The professional development, or training, offered to the teachers for the new curriculum varied in success. Judy struggled with both trainings she received. She felt the SEPUP training was too rigid and did not like that the curriculum was so prescribed. While she saw the benefit in why they trained her in the way she did, it went against her personal beliefs of how science is taught and learned. In contrast, Elizabeth found that her training in the STC kits was very beneficial as the trainer adapted the sessions to fit the needs of the teachers. Delores found she was fighting with the district to receive training prior to implementing the new curriculum.

For Judy, Laura and Delores, the training offered on the curriculum was the first time the teachers interacted with the curriculum materials. This should be a positive experience for the teachers. As their view of the curriculum can be molded at this point, efforts should be taken to ensure that the teachers' values and beliefs are aligned with the new curriculum and that their experience in learning the new curriculum is as free of frustration as possible. Delores interacted with the curriculum materials prior to training as she had selected them. However, she found resistance from her district in providing her and her colleagues training prior to implementing the new curriculum. Instead, the district wanted to offer the training to the teachers at the same time they were implementing the curriculum.

Professional development, or training, of new curriculum should happen in advance of its implementation. Teachers need time to interact with the materials. They need time to see where their values and beliefs fit into the lessons. It is possible that teachers will begin making modifications to the materials prior to training. Therefore, the training can serve as a checkpoint for administrators to ensure that any changes made to the curriculum by the teachers are aligned with science education reform.

What professional development is needed for the teachers can be revealed through phenomenological methods. This is not to say that administrators or curriculum specialists should conduct full phenomenological interviews with their teachers. However, by asking the teachers their beliefs and values in science education, those in charge of curriculum design and implementation can better understand what their teachers will be experiencing and how to help them ensure the success of the new inquiry-based curriculum.

Districts should also provide opportunities for teachers to reflect on modifications to the curriculum. The teachers should be allowed to suggest those modifications be incorporated into the curriculum map or scope and sequence if the modifications are aligned with the curriculum's philosophy. The teachers studied in this dissertation were provided such an opportunity. The four teachers implemented their curriculum faithfully for the first few months before they began making changes. At various points after implementing the curriculum, the teachers were given the opportunity to review the curriculum maps and make changes. They were also asked to align the curriculum to NGSS. This, too, provided an opportunity to make changes, as the sequence of lessons in their kits did not always align with NGSS strands.

Any professional development provided to the teachers should be transformative professional development (Thompson & Zeuli, 1999). This professional development should be provided as soon as possible after a curriculum map or scope is developed. Successful change from professional development cannot be delivered through a one-time workshop. Rather, it must be consistent over an extended period to effectively bring change to the teacher's values and beliefs (Johnson, 2006; Loucks-Horsely et al., 2010; Luft and Hewson, 2014). Although the teachers in this dissertation hold beliefs aligned with reform efforts, they still need guidance in how to reconcile their beliefs with the new curriculum, other reforms, and their own uncertainties of aspects found in both the old and new curriculum. Transformative professional development can serve as a way to guide teachers through that reconciliation and ensure the success of the new inquiry-based curriculum.

Situating Findings into the Academic Literature

The findings of this study are consistent with other studies that have examined the relationship between science teachers' beliefs and the curriculum they teach. These studies reveal that science teachers embed their values and beliefs into the curriculum and affect how they teach their curriculum. Tobin and McRobbie's (1996) study of a high school chemistry teacher found that his beliefs of being powerless in transforming the chemistry curriculum prevented him from making reform-based changes. Cotton (2006) found that environmental science teachers avoided the pro-environmental agenda of the curriculum because they did not believe it was their place to influence students' attitudes. In a general education study, Wallace and Priestly (2011) found that teachers who held beliefs close to reform efforts modified their teaching practices to be aligned with those reforms. But few studies have looked at the relationship between a curriculum transition and the teachers' values and beliefs.

Cronin-Jones' (1991) study was one that did examine this transition in light of teachers' values and beliefs. Her study revealed that science teachers' beliefs about "how students learn, a teacher's role in the classroom, the ability levels of students…, and the relative importance of content topics" (p. 235) impacts the implementation of inquiry-based curriculum. Those beliefs, which are not always aligned with reform efforts, threaten the successful implementation of inquiry-based curricula. These teachers would prohibit successful implementation by relying on teacher-centered pedagogy and focusing on content rather than process. These are counter to the philosophy of the curriculum they were implementing. In this dissertation, each of the four teachers made changes to the curriculum. Yet, unlike in Cronin-Jones' (1991) study, the four science teachers studied in this dissertation held beliefs that were aligned with their new curriculum kits. The changes they made to the kits did not undermine the kits' philosophies.

Cronin-Jones' (1991) study was conducted in part in order to contribute evidence towards the development of a grounded theory that describes how science teachers' beliefs affect the implementation of science curriculum. An example of such a theory that has been developed is Brown's (2009) teacher-tool relationship theory. Brown's (2009) theory offers an explanation as to why teachers make such changes to the curriculum. This relationship includes a two-way influence. The teacher is influenced by the curriculum and the teacher affects how the curriculum is implemented. He argued the curriculum becomes a means through which the teacher can express their values and beliefs. Thus, if the curriculum is not fully aligned with the values and beliefs, teachers will make changes to it. Brown (2009) supported his theory with a body of research that recognized teachers change the implementation of curriculum. He discussed that this occurs as a process of selection, interpretation, reconciliation, accommodation, and modification. Each of these components is rooted within the teacher's knowledge, beliefs, skills, and goals. This dissertation adds further evidence to this theory.

This dissertation contributes to findings from similar studies (Munby, 1984; Cronin-Jones, 1991; Tobin and McRobbie, 1996; Wallace & Kang, 2004; Cotton, 2006; Ozel & Luft, 2013) by looking at veteran middle school and junior high teachers whose values and beliefs are aligned with science education reform. This dissertation finds similar results to teachers changing curriculum to match their beliefs; however, it finds that they positively modified the curriculum to ensure it met their reform-aligned beliefs. This dissertation also contributes that these teachers' reform-aligned values and beliefs are challenged by the traditional model of science teaching at the high school their students will soon attend. The teachers feel under pressure to ensure their students feel prepared for their traditional high school science classes. And, due to the philosophy of inquiry-based curricula and their experiences with the traditional curricula, the teachers are experiencing uncertainty in the role of content and uncertainty in how to grade student work.

This dissertation also fills a gap in the phenomenological research revealing the essence of the experience. It also responds to the call for additional descriptive studies that examine teacher experiences with inquiry learning and teaching. Crawford (2014), in a comprehensive review of literature on teachers and inquiry, concluded that "descriptive and interpretive studies…are vital in understanding all the complexities involved when a teacher strives to carry out teaching science as inquiry" (p. 529). This dissertation responds to the call having examined a group of science teachers whose values and beliefs are aligned with reform efforts.

To summarize, this dissertation adds to the limited research on how experienced science teachers whose beliefs are aligned with reform efforts experience the implementation of new inquiry-based curriculum. The analytical diagram created from that experience can be used as a guide for future professional development. The framework of the diagram may be applicable to the experiences of other teachers as well and may also guide their professional development. However, further research would need to be done as this study was phenomenological and, consequently, has limited generalizability.

This dissertation adds to this limited body showing that experienced, reform-aligned science teachers:

- make changes to the curriculum, albeit without negating the philosophy of the curriculum,
- experience freedom for their beliefs from the old curriculum and embed them, although not perfectly, into the new inquiry-based curriculum,
- must reconcile their beliefs due to negatively held perceptions of aspects of the old curriculum (e.g. the role of content), other reform efforts (e.g. Common Core), and the future needs of their students (e.g. preparation for high school), and
- need support and guidance with other curricular aspects (e.g. incorporating content, grading) that can be different in an inquiry curriculum.

Limitations and Questions for Future Studies

This dissertation used a phenomenological methodology to understand the experience of four veteran science teachers implementing new inquiry curricula. The findings showed that the curricula became a tool through which the teachers could implement their values and beliefs in teaching science. The teachers grappled with the curriculum to find a way to fit their beliefs and values of science education into it. These teachers engaged in a balancing act between ensuring their beliefs are in the curriculum and the other purposes of learning (e.g. processing a non-fiction text or how to study for a test). And, the teachers found ways to make the curriculum more meaningful for their students. Although the teachers made modifications to the kits, the overall philosophy of the curriculum was not undermined.

This dissertation, like all academic research, is not without its limitations. In examining the limitations, however, it is possible to conceive future research studies. One of the limitations of this study is the lack of generalizability. It is difficult to generalize findings from this dissertation as it employed a qualitative, phenomenological methodology. The sample size is small and the examined experience may be unique to the cohort of teachers studied. A question can be raised with regard to the transferability of the findings of this dissertation to similar context with other science teachers. Do other veteran science teachers view the transition from tradition to inquiry-based curriculum as these teachers did? Do they experience the curriculum as a malleable structure that can accommodate their values and beliefs while still maintaining the philosophy of the curriculum?

This dissertation had a modified version of the original interview plans. The original methods planned for three interviews with the teachers. Yet, IRB asked for the first two interviews to be consolidated together to reduce the number of times the teachers would have to meet. Although this did not impact the overall time commitment for each teacher nor did it impact the findings, this consolidation of interviews eliminated a chance to increase the trustworthiness of the findings. In qualitative research, asking similar questions between interviews to see if the answers remain consistent can increase trustworthiness. For example, the teacher who participated in the pilot study also participated in the dissertation. In comparing the responses from the pilot study to the dissertation, I found no difference or variation. That is powerful in identifying that what she said is what she truly means and believes.

This dissertation recruited teachers with specific criteria. The teachers were experienced: two of the teachers have Master's degrees in Science Education; one teacher is an NSTA New Teacher Academy fellow; the teachers have been teaching for many years; each has a strong understanding of science pedagogy. The purposeful selection of these teachers was intentional in order to examine a specific experience. This leaves open further questions based on modifying the selection criteria. Potential questions include how do the experiences of the teachers in this study compare to:

- non-veteran teachers?
- elementary or non-specialized teachers?
- to veteran science teachers who do not teach through best practice?
- to teachers in different socioeconomic districts?
- to teachers in districts in states where NGSS is not adopted or is resisted?

Similarly, the developed analytical model was based on the experiences of these four similar science teachers. Additional research is needed with proposed analytical model to determine if this model works with teachers who believe in traditional science education, inexperienced science teachers, and those who teach in different socioeconomic communities.

Researcher Reflection

To conclude this dissertation, I would like to share a brief self-reflection on my process. Conducting academic research is a huge undertaking and this dissertation was no different. The time to write this dissertation, from its initial pilot study to the final defense was almost 4 years. It is hard to find time to write when you are not actively enrolled in courses at the university. It's freelance work that requires a considerable amount of energy, motivation, and persistence.

However, the end result is extremely rewarding. Working with the four teachers in this dissertation has given me a new appreciation of what happens behind the scenes, so to say, with curriculum implementation. I feel we take for granted what teachers experience. We sometimes forget that teaching is not just an exercise in transferring knowledge to students or preparing lessons for them. Teaching, instead, is a complex process that involves deeply rooted beliefs, those beliefs influencing our decisions of what happens in our classrooms, reflections on what we've done and what we can do better, and grappling with the many aspects of learning that try to get a share of control in our classrooms.

Part of my choice in making this study phenomenological was to reveal that complex process. And, I feel my choice was well made. Speaking with each of the teachers and hearing the passion, frustration, and excitement as they talked was incredibly powerful. The process provided reflection for the teachers and reflection for myself. Reading through my completed study made me ask questions about my own teaching. What are my beliefs in teaching science? Have these beliefs changed over time? What role does content have in my classroom?

I'm also left with excitement for future studies I can conduct. Conducting my literature review and identifying my study's limitations have provided future questions to research. I do not want the end of my doctoral program to also mark the end of my desire to do research. I hope to continue asking questions and finding answers.

Again, I express many thanks and appreciation to all of those who have helped me in completing this dissertation.

References

Baird, J.R. (1999). A phenomenological exploration of teachers' views of science teaching. *Teachers and Teaching: Theory and Practice, 5*, 75-93.

Brown, M.W. (2009). The teacher-tool relationship: Theorizing the design and use of curriculum materials. In J.T. Remillard, B.A. Herbel-Eisenmann, and G.W. Lloyd (Eds.) *Mathematics teachers at work: Connecting curriculum materials and classroom instruction* (pp. 17-36). New York, NY: Routledge, Taylor-Francis.

Cotton, D. R. E. (2006). Implementing curriculum guidance on environmental education: The importance of teacher beliefs. *Journal of Curriculum Studies, 38*(1), 67–83.

Crawford, B.A. (2014). From inquiry to scientific practices in the science classroom. In N.G. Lederman & S.K. Abell (Eds.), *Handbook of research on science education,* 2nd edition, (pp. 515-541). New York, NY: Routledge.

Cronin-Jones, L.L. (1991). Science teacher beliefs and their influence on curriculum implementation: Two case studies. *Journal of Research in Science Teaching, 28*(3), 235-250.

Johnson, C.C. (2006). Effective professional development and change in practice: Barriers science teachers encounter and implications for reform. *School Science and Mathematics, 106*(3), 150-161.

Keys, C. W. & Bryan, L.A. (2001). Co-constructing inquiry-based science with teachers: essential research for lasting reform. *Journal of Research in Science Teaching, 38*(6), 631-645.

Levitt, K. E. (2001). An analysis of elementary teachers' beliefs regarding the teaching and learning of science. *Science Education, 86*(1), 1-22.

Loucks-Horsley, S., Stiles, K.E., Mundry, S., Love, N., & Hewson, P.W. (2010). *Designing professional development for teachers of science and mathematics*. Thousand Oaks, CA: Corwin Press.

Luft, J.A., and P.W. Hewson. (2014). Research on teacher professional development programs in science. In N.G. Lederman & S.K. Abell (Eds.), *Handbook of research on science education,* 2nd edition, (pp. 889–909). New York, NY: Routledge.

Munby, H. (1984). A qualitative approach to the study of a teacher's beliefs. *Journal of Research in Science Teaching, 21*(1), 27–38.

Ozel, M., & Luft, J. A. (2013). Beginning Secondary Science Teachers' Conceptualization and Enactment of Inquiry-Based Instruction. *School Science & Mathematics*, *113*(6), 308-316.

SEPUP. (2009). *Issues and life science: Teacher's guide*. Ronkonkoma, NY: Lab-Aids, Inc.

Smithsonian Institution (2013). *Investigating biodiversity and interdependence*. Burlington, NC: Carolina Biological Supply Company.

Thompson, C. L., & Zeuli, J. S. (1999). The frame and the tapestry: Standards-based reform and professional development. In L. Darling-Hammond & G. Sykes (Eds.), *Teaching as the learning profession: Handbook of policy and practice* (pp. 341-375). San Francisco, CA: Jossey-Bass.

Tobin, K., & McRobbie, C.J. (1996). Cultural myths as constraints to the enacted science curriculum. *Science Education, 80*(2), 223-241.

Wallace, C.S. & Kang, N. (2004). An investigation of experience secondary science teachers' beliefs about inquiry: An examination of competing belief sets. *Journal of Research in Science Teaching, 41*(9), 936-960

Wallace, C. S., & Priestley, M. (2011). Teacher beliefs and the mediation of curriculum in Scotland: A socio-cultural perspective on professional development and change. *Journal of Curriculum Studies, 43*(3), 357–381.

Yerrick, R., Parke, H., & Nugent, J. (1997). Struggling to promote deeply roote change: The "filtering effect of teachers' beliefs on understanding transformative views of teaching science. *Science Education, 81*(2), 137-159.

Appendix A:

Interview Guide – Interview One

Opening: Thank you for taking time to have an interview with me. As teachers, we encounter changes to what we teach. These changes bring with them many emotions, feelings, struggles, and successes as we navigate to adopt them into our classrooms. These interviews will help me understand how science teachers experience the adoption of a new curriculum. Your interview will be helpful in adding to the limited amount of research on teacher experiences in adopting science curriculum kits. I ask that you please be as descriptive as possible in responding to these questions, as it will help me understand your experiences and background. Do not be worried if you feel a thought or idea is incomplete as anything you add to this conversation will be valuable.

This conversation is being recorded for research purposes. Please let me know now if you do not agree to being recorded. You may request that the recording stop at any time. The recording will be transcribed verbatim. Please know that your identity, the identities of anyone you mention, and locations will be kept confidential with the use of pseudonyms.

Would you like to select a pseudonym to use before we begin?

Are there any questions you have for me before we begin?

Primary Question	Guides
Please tell me about how you decided to go into teaching.	What were your inspirations? What were your feelings about school growing up?

How did you come to be a *science* teacher?	What were some positive experiences you had with science while growing up?
	What were your feelings about science while growing up?
	What was your background in college with science?
	    What kind of science classes did you take?
	    What was your "science major"?

What is your teaching background?	How long have you been teaching? Have you always taught at the same school? What motivated you to change schools? What subjects have you taught? What do you currently teach? What professional development have you taken related to

	science education?
What is your teaching philosophy?	What is the foundation for your philosophy? How do you implement your philosophy in your classroom? What challenges do you face in following your teaching philosophy?
How do you identify yourself as a science educator?	How would you describe your understanding of science? Why? How would you define a scientist? Do you identify yourself as a scientist? Why or why not? What does it mean to be a science teacher? What do you believe is important in teaching science?
If you had unlimited resources and time, how would you teach science?	What resources would you want? Why would you teach it that way? How does this compare to the resources you currently have to teach with?
Why do we have our students learn science?	What is the purpose of students learning science? What are the most important things for students to learn in science? Why?
What do you believe students struggle with the most in science?	How do you respond to these struggles?
What is a typical science unit/lesson like in your classroom?	What are your roles as the teacher? What are the roles of the students? How do students participate in the lessons?
Can you please describe for me what you taught prior to the new curriculum adoption?	What was your experience in learning the old curriculum? What were the major, underlying goals or purposes of the curriculum? What specific topics were taught? What types of resources did you use to teach the curriculum? Describe the balance of content and activity. How did student obtain content knowledge? How often were students given content? What was the role of activities, labs, or experiments in the curriculum? (What purpose did they serve?) What role did the students have in the curriculum? (More open exploration, guided, procedural, etc.?) How were students assessed with this curriculum?

	What was being assessed? (Content knowledge, skill, application of ideas, etc.?)
What do you feel were the strengths and weaknesses of the old curriculum?	No probes.
Describe any changes you made to the former curriculum to meet the needs of the students.	How did you add or remove lessons? (What lessons were added or removed and why?) How did you address the needs of students with learning disabilities? How did you address the needs of students who are above grade level?
Are your teaching philosophy and beliefs of science represented by the old curriculum?	How did the curriculum align with your beliefs as a science educator? (Explain why.) How did the curriculum align with your beliefs of what science is, how it is done, and how it should be taught? (Provide examples to support this.)
How comfortable were you teaching the old curriculum?	How long did you teach it? What was your experience like teaching it for the first time? How does this compare to your experience teaching it now?

Do a quick check of topics to make sure everything was covered.

Closing*: Thank you for your time. Before we end the interview, is there anything else you would like to add?*

If no….
Tell the participant: *I will e-mail you a PDF of the transcript within the next 3-4 days. When you receive the transcript, please review it and let me know if there is anything you would like to clarify, revise, or remove. You can either e-mail those changes to me or tell me at the next interview. If you need more time to review the transcripts, please let me know and I will accommodate your request.*

Confirm scheduled time for next interview.

Thank you again for meeting with me!

Appendix B:

Interview Guide – Second Interview

Opening: Thank you again for taking time to have a second interview with me. In our first interview, we discussed the old curriculum that was taught in your school. Now, I'd like to focus on the new curriculum: why it was changed, how it was changed, what was changed, and how the curriculum change felt to you.

This conversation is being recorded for research purposes. Please let me know now if you do not agree to being recorded. You may request that the recording stop at any time. The recording will be transcribed verbatim. Please know that your identity, the identities of anyone you mention, and locations will be kept confidential with the use of pseudonyms.

Are there any questions you have for me before we begin?

Primary Question	**Guides**
Why was the curriculum changed?	What were the deciding factors in deciding to change the curriculum?
How was the new curriculum designed?	Were you part of the design process? How were your opinions about the curriculum incorporated into the design process?
What concerns did you have as the new curriculum was being designed?	Who did you address these concerns to? How were your concerns handled?
How were you trained for the new curriculum?	What was your experience like? How were you treated as a teacher? (In context of your own background)
What is being taught under the new curriculum?	What are the major goals of the curriculum? What are the specific topics being taught? What curriculum kit(s) are you using? Describe it briefly.
What do lessons look like in the new curriculum?	
What role do the students, the teacher, and the content play in the curriculum?	What are the expectations of the students? How is the teacher positioned in the classroom? Are they a guide, lecturer, etc.? How do students receive content in the lessons?

What are the strengths and weaknesses of the new curriculum?	No probes
How have you felt while teaching lessons from the new curriculum?	Can you describe in a detail a lesson you did? How did you feel about that lesson? What would you change about that lesson for the next time you do it?
How comfortable are you teaching the new curriculum?	
How does the new curriculum align with how you vision science being taught?	How does it align with what you believe students should be doing in science? How does it align with your personal beliefs about why students should learn science?
Please describe for me the Next Generation Science Standards.	What is the purpose of the new standards? How do you feel about the new standards (as compared to the previous state/national standards)? How do the standards align with your personal beliefs about how and why students should be taught science? How does the curriculum (and science kit) align with the new standards? Do you think the curriculum is successful in meeting the standards? How have you incorporated the standards into your curriculum?

Do a quick check of topics to make sure everything was covered.

Closing*: Thank you for your time. Before we end the interview, is there anything else you would like to add?*

If no….

Tell the participant*: I will e-mail you a PDF of the transcript within the next 3-4 days. When you receive the transcript, please review it and let me know if there is anything you would like to clarify, revise, or remove. You can e-mail those changes to me.*

In the same e-mail, I may ask you to clarify what you have said in the interview. If that happens, please include that with your reply. I ask that you e-mail any changes and response to clarification questions within a week. If you need more time than that, please let me know and I will accommodate your request.

Please do not hesitate to contact me, my faculty advisor, or the DePaul Office of Research Services if you have any questions regarding the study.

Thank you again for providing time to meet with me and share your experiences. It is greatly appreciated!