VERTICALLY ALIGNED PROFESSIONAL LEARNING COMMUNITIES AS A KEYSTONE FOR ELEMENTARY SCIENCE TEACHER PROFESSIONAL DEVELOPMENT, GROWTH, AND SUPPORT

by

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Many school districts do not require science in the elementary school curriculum or place significantly more emphasis on the performance of students on the ELA and Math tests. With science education shifting to the Next Generation Science Standards (NGSS), there is a critical need for high quality science instruction in elementary schools. This study examines the experiences of 28 elementary teachers engaged in a science education professional development program that was comprised of 60 kindergarten through twelve grade teachers. I examine the experiences of the 28 elementary teachers as they work in vertically aligned professional learning communities with middle and high school teachers. Findings in this study indicate that the model provides a supportive environment for elementary teachers to grow and develop both personally and professionally in their science teaching practice. Evidence is presented that shows how a learning community of elementary, middle and high school teachers can provide an opportunity for elementary teachers to socially construct knowledge of how to best support student success in science. Additionally, the findings show that elementary teachers are able to socially construct knowledge about effective teaching practices in science that support core science teaching practices. The findings also indicate that the nature of these learning communities also provided many structures that can support increased efficacy amongst elementary science teachers. Finally, the experiences of elementary teachers engaged in his study were overwhelmingly positive, leading to increased trust and respect amongst peers and improved confidence and motivation to teach science at the elementary level.
DEDICATION

I dedicate this work to my wife, Mary Catherine Hillman, without whom I would never have begun my journey into the academic world. Thirteen years ago, I was an immigrant with no formal education after secondary school. Without Mary’s steadfast patience, love and encouragement I would have never made it to this point. I also dedicate my work to my children, Charles Edward and Claire Elizabeth. I apologize that in recent months you may have forgotten what I look like or wondered why my brain seemed to be elsewhere most of the time. I am thankful for you every day and look forward to creating many more memories with you in the future.
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Over the last three years, my family experienced a tragic sequence of events that took us to the very depths of despair. In the midst of this we experienced the immense joy of welcoming a new child. This experience was even more intense because of how close to death my wife was immediately after labor. There are many people who have supported me before, during and after these events and I wish to acknowledge this. What I write here will never fully express the true extent of how grateful and blessed I feel to have had their support during this period.

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Chapter I

INTRODUCTION

Science “is more than a school subject, or the periodic table, or the properties of waves. It is an approach to the world, a critical way to understand and explore and engage with the world, and then have the capacity to change that world, and to share this accumulated knowledge. It’s a mindset that says we that can use reason and logic and honest inquiry to reach new conclusions and solve big problems.” (President Obama, 2015)

In recent years there has been much change in the United States regarding education reform. Of particular interest to science educators are the new national science standards, the Next Generation Science Standards (NGSS) (Lead States, 2013). This new set of national standards was preceded by a precursor framework document that laid the groundwork for NGSS, A Framework for K-12 Science Education (National Research Council, 2012). The contents of this document and the reforms upon which it was based are also important to consider when one examines the science teaching of the future. In the following sections, some historical context for the study is provided, as well as a summary of reforms in science education and a brief discussion about the implications for practice that K-12 science educators are facing.
Glossary of Terms

Community: In this study, community is used to describe the various individuals found within the day to day functioning of the fellowship. This includes both the leadership team and the fellows.

Fellow: A teacher who is chosen to be a member of a science education program administered by a university located in the northeast. In order to become a fellow, teachers complete an application process and are recommended by their district administrators. Teachers chosen to become fellows join a cohort who are active participants in the program over a two-year period. During this time, fellows receive a stipend for each of the two years and in turn are expected to complete all the requirements for the fellowship. The fellows represent a diverse group of K-12 science teachers. The range of classroom experience varies wildly from 3 years to 30 years.

K-12 vs. K-5: In this study K-12 refers to the range of grade levels between kindergarten and twelfth grade. Whereas, K-5 refers explicitly to the range of grade levels found mainly in elementary schools.

Leadership Team: The leadership team comprises the two co-directors, the grant manager, and myself in the role of project manager and researcher. All individuals are involved in supporting the fellows throughout the program. The leadership team works with fellows individually and as a whole during year one at monthly meetings and second year quarterly meetings.

Science Education Fellowship (SEF): The SEF in this study is a two-year fellowship that serves a cohort of 20 K-12 science teachers. The fellowship is supported by a privately funded grant and consists of one year of intensive professional
development followed by a second year of individual project work under the mentorship of a university faculty member.

**Vertical Articulation:** The three dimensions of Next Generation Science Standards (NGSS) provides students with a context for the content of science, how science knowledge is acquired and understood, and how the sciences are connected through concepts that have universal meaning across the disciplines (The Next Generation Science Standards Executive Summary [Press Release], 2013). Vertical articulation refers to scientific knowledge, content, concepts, and phenomena as they should grow and develop over the time a student will spend in school. Vertical articulation is important in this study because the switch that must occur in schools requires science curricula and instruction at each level of the K-12 system to build on each other.

**Vertically Aligned Professional Learning Communities (V-PLCs):** V-PLCs are groupings designed to provide fellows context of and experiences in the progression of science for students as expected in the NGSS. The V-PLCs are comprised of five fellows representing a range of grades between kindergarten through twelfth (K-12).

**Historical Context and Rationale for the Study**

In 1989 the American Association for the Advancement of Science (AAAS) Project 2061 published the book, *Science for All Americans*. Project 2061 is a long-term AAAS initiative which aims to achieve science literacy for all Americans and the book clearly laid out and defined understandings and ways of thinking that were considered
essential for all Americans in the modern scientifically and technologically focused world *(Science for all Americans, 1989).*

As part of a sustained push for scientific literacy, the AASS Project 2061 published *Benchmarks for Science Literacy* (1993). This book was based on the science literacy goals of *Science for All Americans* and stated what students who were making reasonable progress should be able to know and be able to do in science, mathematics and technology by the end of grades 2, 5, 8, and 12. AAAS points out that the benchmarks were not a curriculum, framework, or curriculum plan. Instead, the benchmarks are described as a sequence of specific learning goals that can be used to design a core curriculum (AAAS - Project 2061 - Benchmark for Science Literacy, 2013).

The *National Science Education Standards* (NSES) were coordinated by the National Research Council (NRC), who established the National Committee on Science Education Standards and Assessment (NCSEAA) to support the development process. The NCSEAA was comprised of representatives from the National Science Teachers Association (NSTA), AAAS, American Chemical Society (ACS), the American Association of Physics Teachers (AAPT), the Council of State Science Supervisors (CSSS), the Earth Science Education Coalition (ESEC), and the National Association of Biology Teachers (NABT). The overall vision of these standards was to achieve scientific literacy for all students using *Science for All Americans* as a guide and *Benchmarks for Science Literacy* for content guidance. The standards were organized into groups that included standards for science teaching, professional development for teachers of science, assessment in science education, science content, science education programs, and science education systems (National Research Council, 1996).
There is one difference that is immediately obvious between NGSS and NSES. NSES has standards for the different players within the educational system. The broad content standards provide a general overview of what topics students should be learning, what science teachers should know, what science teacher professional developers should include, and/or guidance for how science education programs should create consistency within. In addition, NSES also has systems standards, that are aimed more at the district/policy level.

The NGSS on the other hand contains performance expectations that are made up of science and engineering practices, disciplinary core ideas, and crosscutting concepts. These performance expectations are effectively the policy statements for the grade level and the three component pieces serve as guidelines for teachers, curriculum and assessment developers (National Research Council, 2012).

*A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (The Framework) is a publication by the National Academy of Sciences (NAS) and the Carnegie Corporation of New York (CCNY). The document details the findings from a committee of science education experts, who studied and created a broad framework of expectations for K-12 student learning in science. The committee identified two significant reasons that a new set of science education standards was necessary.

First, the previous science education standards, the National Science Education Standards (NSES), were almost 15 years old and as indicated in the paragraphs proceeding this, much had changed in this time period. Second, there was a unique opening for a national set of science standards as the states were currently involved in the
adoption of national English language and mathematics standards (Common Core State Standards [CCSS]). The vision of the committee was that all students will learn to appreciate the beauty and wonder of science and possess sufficient knowledge of science and engineering to engage in public discourse in related issues. The committee set out to create a series of guidelines for the development of students, including content, sequence, and learning expectations. The committee explicitly identified that their work was not designed to provide grade-by-grade detail or course descriptions/standards (National Research Council, 2012). The committee attempted to systematically organize K-12 science education and recommended that science education be built around the three dimensions listed below:

- Scientific and engineering practices
- Crosscutting concepts that unify the study of science and engineering through their common applications across fields
- Core ideas in four disciplinary areas: physical science; life science; earth and space sciences; and engineering, technology, and applications of science.

(National Research Council, 2012)

The National Research Council (NRC) and Achieve, Inc. developed the *Next Generation Science Standards (NGSS)* using the vision provided by The Framework document. Significant national collaboration was involved in the development of the NGSS as 26 states and 40 writers worked together in creating the new standards (National Research Council, 2012). Building on The Framework, NGSS integrates three dimensions of science essential for providing a high-quality science education for all K-12 students. These three dimensions are practices, crosscutting concepts, and disciplinary
core ideas (DCI). The integration of these three dimensions provides students with a context for the content of science, how science knowledge is acquired and understood, and how the sciences are connected through concepts that have universal meaning across the disciplines (National Research Council, 2012).

The overall vision of the NGSS is similar to that of The Framework—all students will learn to appreciate the beauty and wonder of science and possess sufficient knowledge of science and engineering to engage in public discourse in related issues. The NGSS vision also includes the following: integration of content and application in an effort to reflect how science and engineering is practiced in the real world; a progression of knowledge throughout a student’s entire K-12 scientific education that is focused on deeper understandings and application; an increased awareness of core ideas of engineering design and technological applications; the desire to ensure that all students learn about the complex interactions between science, technology, society and the environment, while learning critical thinking and communication skills. Essential to all of the above components is that the NGSS vision is focused on preparing students for college and careers and the integration of CCSS helps to ensure that science and engineering is an integral part of a student’s comprehensive and aligned education (National Research Council, 2012).

**Implications for K-12 Science Educators**

The Next Generation Science Standards (NGSS) present a view of K-12 science instruction in which a “progression of knowledge occurs from grade band to grade band
that gives students the opportunity to learn more complex material, leading to an overall understanding of science by the end of high school” (Lead States, 2013, p.3). In order for this approach to be realized, and for students to experience cohesive science instruction that builds on what they have mastered, science teachers must be more aware of the curriculum and instruction at all grade levels in their district and be familiar with the vertical articulation of the standards laid out in the NGSS, from grades K-12.

Traditional approaches to curriculum in science classrooms have rarely been enacted in ways that permit students to build their understandings of scientific concepts and practices cumulatively over time to develop more in depth and complex understandings (Cheung, Slavin, Kim, & Lake, 2017; Darling-Hammond et al., 2015; Duschl, Schweingruber, & Shouse, 2007; Keeley, 2015). An examination of science curricula reforms since the 1960s, identifies that attempts to reform science curricula have been based heavily on theories of teaching, rather than theories of learning (Duschl et al., 2007), focused on a high level of academic rigor associated closely with the principal scientific disciplines rather than the experiences or connections more common to students (DeBoer, 2000), and approached science inquiry as a series of steps and anticipated processes for the teacher and student (DeBoer, 1991, 2000; Duschl et al., 2007; Karplus & Thier, 1967), for example, the ‘learning cycle’ as proposed in the Science Curriculum Improvement Study (Karplus & Thier, 1967). The Framework and subsequently the NGSS are designed to provide science curricula that is based on theories of student learning about science both in and out of school (Duschl et al., 2007; NRC, 2012)
Improved science teacher awareness of the vertical progression of scientific knowledge expected in NGSS would allow for the increased understanding of the level of knowledge and understanding a student is expected to meet during each step of their academic career. Teachers’ knowledge and understanding for teaching science varies by grade. In most states, secondary science teachers are required to take more coursework in science content knowledge than elementary school teachers who teach science in addition to other content areas. A focus on the vertical articulation of science knowledge and content as called for in NGSS may be one way to help teachers see the connections between the science content the teacher covers in their curriculum, high quality science teaching practices, and the science a student is exposed to over the course of their school career.

**Purpose of the Study**

Considering that an increasing number of states are incorporating the NGSS as their standards for science education, there is a steadily increasing necessity for science teaching that is in line with the philosophy of NGSS. In the case of my work, the state in which I conducted my research integrated NGSS into the state science learning standards in September 2017. Thus, kindergarten to 12th grade teachers of science in my state (New York) are expected to execute a type of teaching that they were not prepared for and that runs counter to traditional science pedagogy. Elementary teachers are predominantly prepared as generalist teachers and often lack adequate background content knowledge for teaching science. Additionally, the limited science teaching that occurs within elementary classrooms is often traditional by nature and/or lacks a clear
link to science content or concepts. The situation is particularly grave because an underlying expectation in the NGSS is that all students will receive exposure to high quality science teaching in elementary schools. Thus, the focus of this study is to examine a new model for teacher development which uses vertically aligned professional learning communities (PLCs) and to investigate the supports and benefits afforded to elementary science teachers to help them improve their practice as necessary for the NGSS. Additionally, I examine PLCs aligned vertically, K-12, through the perspective of participating elementary science teachers to identify the positive personal and professional outcomes of the experience.

**Research Questions**

The research questions guiding this study are as follows:

1. How does participation in a vertically-aligned professional learning community support elementary teacher growth and knowledge development in supporting student success in the elementary science classroom?

2. How and why does participation in a V-PLC support practicing elementary science teachers’ knowledge and development of practices that support the discourse based three core high-leverage teaching practices in science?

3. How do vertically-aligned professional learning communities create an environment that supports opportunities for improving self-efficacy?

4. Why do practicing elementary science teachers view the vertically-aligned professional learning model as beneficial for their personal and professional development?
Format of the Dissertation

This dissertation is composed of a literature review (Chapter II), methodology and context (Chapter III) and three separate research papers (Chapters IV, V, and VI). The final chapter (Chapter VII) addresses a discussion of the three paper findings and implications in the field.
Chapter II

LITERATURE REVIEW

In this chapter, I introduce and discuss what is reported in the literature about each of the major components and associated facets of my study. A brief overview of the Next Generation Science Standards (NGSS) and the organization of this document is provided. I explain how these might impact practicing elementary teachers and a brief overview of the pre-existing issues in elementary teacher preparation is also described and discussed.

The NGSS and Implications for Practicing Elementary Science Teachers

The NGSS are organized by grade band levels K-5 and 6-12. The grade bands were identified in The Framework and are utilized in the NGSS as learning progressions. Learning progressions can be described as progressively more sophisticated ways of thinking and reasoning about a particular concept or content area that develop and build on one another as students learn more (Duncan & Hmelo-Silver, 2009; Duncan & Rivet, 2013; Smith, Wiser, Anderson, & Krajcik, 2006). In science, the notion of learning progressions is not entirely new. Indeed, the idea of a 'spiraling curriculum' in which students are exposed to the same content and concepts over the course of their school
career, each time building the amount of detail and depth of understanding required, was suggested in the 1960s by Bruner (1960).

The standards are broken down into performance expectations that integrate three dimensions for learning, science and engineering practices, disciplinary core ideas and crosscutting concepts (National Research Council, 2012). Science and engineering practices are designed to incorporate the ways in which scientists explore the world around them and engineers design and build systems. Disciplinary core ideas (DCIs) are the key ideas or concepts within science, these often have broad applications across various fields within science and engineering, yet in the standards are grounded within one of four domains, earth and space science, engineering, life science and physical science. Finally, crosscutting concepts include a variety of concepts that support student learning across the four domains and see the connections that exist between them. Performance indicators within NGSS can be searched by DCI, topic, or by individual performance indicator. The various components in the new structure can be seen below in Figure 2.1. The three dimensions identified for science learning in the NGSS are designed to support the development of critical thinking and communication skills that students will need in the 21st century. Additionally, the standards are designed to build knowledge of science over the course of the K-12 schooling experience. This means there is an expectation that students will received a large amount of their background knowledge in science during their time in elementary school.
The NGSS represent a new way of envisioning science learning and teaching in K-12 classrooms far different from how teachers have been traditionally prepared to teach science and much different from how most teachers learned science themselves. A
review of the Journal of Research in Science Teaching, the Journal of Science Teacher Education and other relevant peer reviewed education journals between the years 2014 – 2018 found 234 studies that examined science teaching with an emphasis on NGSS aligned teaching. 132 articles were deemed inappropriate for this review because the study was based in a middle or high school setting. 63 articles were also eliminated because the study focus was preparing pre-service elementary science teachers.

Of these 234 studies, 132 were focused on Middle or high school only, 63 were focused on pre-service elementary science teachers and only 39 were focused on supporting current elementary science teachers integrate the NGSS into their practice. These papers focused on: Literacy; Access, power and diversity; Scientific agency or identity; Aligning curriculum to NGSS; Science teaching practices; Instructional materials (including textbooks); Professional development; Scientific argumentation or explanations; Teaching engineering.

K-12 science instruction as envisioned by the NGSS sees science learning as a sequential progression through each grade band, ultimately, providing students with a deeper and more complex understanding of science by the end of grade 12 (Lead States, 2013, p.3).

In order for this approach to be realized, there are a number of things science teachers must become more aware of in regarding to curriculum and instruction. First, they have to become familiar with all grade levels in their district and familiar with the vertical articulation of the standards laid out in the NGSS from grades K-12 (Reiser, 2013). Second, teachers need to be aware of the manner in which their practice must now shift from presenting facts to explaining how and why phenomena occur (Passmore &
Svoboda, 2012). Third, science teachers also need to become familiar and comfortable with the idea of discourse driving learning and discovery (Duschl, 2008), while also learning to support and orchestrate discussion in their classroom to facilitate the practices (Alozie, Moje, & Krajcik, 2010).

**Elementary Science Teaching: The ‘Elephant’ in the Room**

While the NGSS represents a research and policy-based shift in expectations for students, the generally accepted understanding of what is happening in elementary science teaching is very much opposite to what the NGSS set out to achieve (Roth, 2014). One major criticism of elementary school science teaching is that elementary teachers have traditionally been prepared as generalist educators (Kier and Lee, 2017) with very little focus if any on science teaching during their teacher coursework (Appleton & Kindt, 1999). In addition to this, many elementary teacher candidates and practicing elementary teachers have an inadequate academic background for teaching science (Lee et al., 2008; Tilgner, 1990; Tosun, 2000). The combination of poor preparation to teach science and an insufficient academic background in science result in a dearth of confidence and desire for teaching science at the elementary level (Abell & Roth, 1992; Appleton, 2013; Avraamidou, 2013; Gunning & Mensah, 2011).

While there is significant concern about the preparation and suitability of elementary teachers for science teaching, there is also wide-ranging concern about district and government policy that has focused on ELA and Mathematics above all else. Often district and government policies have had a direct, detrimental impact on science in elementary school (Blank, 2012; Buczynski & Hansen, 2010; Mensah, 2010). Such
shortsighted policy decisions and ‘business as usual’ teacher preparation programs have resulted in national concern over the state of elementary science teaching in the United States (Olson et al., 2015).

**Professional Development**

Interest in better understanding the effectiveness of science teachers is mentioned in a chapter entitled Research on Teaching Science by Watson (1963) in the *Handbook of Research on Teaching* edited by Gage (1963). In this chapter, Watson (1963) identifies two interesting ideas. Firstly, in this era, the National Science Foundation (NSF) had taken the position that teachers who have a greater command of the subject will be able to teach better. In line with this viewpoint, the NSF was funding teacher development programs that exposed teachers of mathematics and science to more content, with the goal of improving the quality of instruction and teachers’ content familiarity. Secondly, Watson describes the belief that teacher behaviors are an indicator of the level of instructional quality and proposes several avenues of research which could be investigated to further knowledge in this area, consequently, building knowledge of what behaviors teachers need to be most effective in science teaching.

In the Second Handbook of Research on Teaching, Shulman and Tamir (1973), also acknowledge the notion of teacher behaviors and the impact these may have on student success, but in addition they began to focus more on the how and why a change in behaviors might occur and if this change would then have a comparable impact on student knowledge assimilation. Additionally, in the early 1970s Piaget’s theory of human development began to its rise to prominence in the field, which set the stage for
science educators to understand the way in which children create their knowledge as constructionist by its very nature (White & Tisher, 1986), and subsequently researchers in the field of science education began to see and investigate the role of the science teacher within this continuum.

It is worthwhile noting that very little science education research at this point focused on teacher development, rather the research looked at the role of the teacher in developing the student. The idea of examining teacher professional development or staff development, is discussed by Griffin (1983). Griffin reviews the very limited research in the area and makes several suggestions for implementing effective staff development within a school.

In the 1990 publication, Handbook for Research on Teacher Education by Houston (1990), there are two chapters that examine staff development. In the first of these chapters, Models of Staff Development, Sparks and Loucks-Horsley (1990) discuss five models of staff development. They conclude that the field is still emerging and is mainly theoretical and descriptive. Additionally, they express the importance of ‘support’ in the various facets of staff development (Sparks & Loucks-Horsley, 1990). In the second chapter, Teacher Development, Burden (1990) discusses an approach to teacher development that is commensurate to teacher experience and career stage. Burden also incorporates some early adult learning theory in this chapter and concludes that much research is needed on the nature of teacher changes and the processes that are expected to be utilized to achieve these changes (Burden, 1990).

In the Handbook of Research on Science Teaching and Learning, edited by Gabel (1994), there are many references to science teacher professional development and
several case studies that use different strategies to support science teacher development. Furthermore, several studies have pointed out flaws in the traditional professional development models. In particular the inability of such models to support teacher development of effective practices (Borko, 2004; Day, 1999; Sandholtz, 2002; Walton, Nel, Muller, & Lebeloane, 2014), the problem of enactment, in which teachers learn a new practice in one context but fail to enact it in their classroom context due to habit (Darling-Hammond, 2012; Kennedy, 1999, 2016; Lampert, 2010), and the disconnect between the learning and teaching contexts which is often the result of traditional “teacher skill delivery” approach to professional development (PD) (Knight, 2002; Muijs & Reynolds, 2017).

The NGSS standards call for substantial modifications to the content and form of teacher instruction (Polikoff, 2014). As a consequence, professional development (PD) for all teachers will need to become significantly more aligned to NGSS if there is to be useful PD for current practicing teachers. According to Wilson (2013), “the U.S. PD system is a carnival of options” (p. 310). Reiser (2013) suggests that professional development for science teachers must become far more consistent and address areas in meaningful and focused ways. Reiser also includes the following key components for successful NGSS PD for currently practicing teachers. PD must be: (a) deeply embedded in subject matter; (b) designed to involve active learning; (c) able to connect teachers to their own practice; and (d) part of a coherent system of support. Similarly, from other researchers, effective PD must be deeply embedded in the content (Banilower, Heck, & Weiss, 2007; Cohen, 1990; Garet, Porter, Desimone, Birman, & Yoon, 2001), designed to involve active learning (Banilower et al., 2007; Mundry & Loucks-Horsley, 1999), able
to connect teachers to their own practice (Fullan, 2007; Loucks-Horsley & Matsumoto, 1999), and part of a coherent system of support (Reiser, 2013). Additionally, effective PD needs to occur over a sustained period of time (Crawford et al., 2014; Sandholtz & Ringstaff, 2016).

**Professional Learning Communities**

In an educational context, professional learning communities (PLCs) emerged in the latter half of the 1980s, originally being termed “learning communities” (Hord, 1997). The concept of the learning community originates from the business domain, where there was an increasing need within organizations to share, develop and nurture professional knowledge, also known as human capital, in an attempt to promote the building of knowledge, leadership and innovation from within organizations. Learning communities are defined as a group of people that act on an ongoing basis to develop their knowledge of a common interest or passion by sharing individual resources and by engaging in critical dialogue (Wenger, McDermott, & Snyder, 2002). While PLCs do not differ greatly from learning communities, the educational context has been relatively well studied such that there is broad consensus for the definition. For example, Hord’s (1997) commonly used definition describes PLCs as a community of “Five Dimensions.” These are 1) supportive, shared leadership, 2) collaborative learning with a student needs focus, 3) shared vision and values focused on student learning, 4) supportive structural and interpersonal conditions, and 5) shared practice (Hord, 1997; Hord & Sommers, 2008).
Shortcomings of PLC Models for Sustainability. In the last several decades there has been much advancement in the knowledge of the skills and content that are needed to achieve educational reform (Hord, 1997). While PLCs are enthusiastically acknowledged as important for encouraging and supporting professional growth among teachers, there is a lack of knowledge in the literature about how PLCs are developed and sustained over time (Dooner, Mandzuk, & Clifton, 2008; Popp & Goldman, 2016) and the nature of the relationships that exist between participants (Lee, Zhang, & Yin, 2011).

Multiple examinations of PLCs in the literature have identified that when teachers are engaged in learning communities there are many benefits. These include, among other things, higher commitment levels and improved effectiveness, the creation and sharing of a large body of professional knowledge, a shift in school culture towards shared decision making, and a positive impact on longevity of teachers’ careers (Darling-Hammond, 1996; Hord, 1997; McLaughlin & Talbert, 2006; Rosenholtz, 1989). However, lacking in the literature is knowledge about how science teachers can effectively interact and collaborate with fellow science teachers through the inquiry-based design that PLCs are built around (Dooner et al., 2008; McLaughlin & Talbert, 2006). Finding ways to best support science teachers’ growth and practice is a priority and requires more research in varied methods to meet the demands of our changing world for educating future citizens (Fulton, Doerr, & Britton, 2010). As well as the aforementioned issues, the literature is deficient of studies that examine science teachers PLCs aligned to reflect the grade band-based progression of knowledge or the interconnectedness of traditionally separated topics within science, as laid out in the NGSS. A focus on the vertical and horizontal articulation of science content as called for
in NGSS may be one way to help teachers see the connections between the science content the teacher covers in their curriculum and the science a student is exposed to over the course of their school career.

Betrand, Roberts and Buchanan (2006) reported that a vertically aligned team initiative showed positive improvements in student skill and knowledge acquisition. In addition, teachers reported support for the initiative and felt that their instruction and curriculum alignment had benefited as a result. Vertically aligned PLCs, or as identified in this study, were supported by vertically aligned coaching and collaboration for learning in science groups (V-CCLS).

In the last several decades there has been much advancement in the knowledge of the skills and content knowledge needed to improve teaching and support educational reform (Hord, 1997; Vanblaere & Devos, 2016). While PLCs are enthusiastically acknowledged as important for encouraging and supporting professional growth among teachers, there is a lack of knowledge in the literature about how PLCs are developed and sustained (Dooner, Mandzuk, & Clifton, 2008; Jones, Gardner, Robertson, & Robert, 2013; Tichnor-Wagner, Harrison, & Cohen-Vogel, 2016).

**Theoretical Framework**

I believe that we learn from our everyday experiences, interactions with the physical world around us and exchanges with other individuals present in our world. I ground my study in the theoretical perspective of constructivism and social-constructivism which are a suitable fit with my own philosophy.
**Constructivism**

Constructivism is a theory of learning grounded in Piagetian theory which essentially posits that individuals construct their own knowledge through interactions that occur between the thoughts or ideas of the individual and their experiences in the world surrounding them (Piaget, 1977). Palincsar (1998), explains that constructivism can be described as learning and understanding that are intrinsic and socially based. Palincsar also explains that “cultural activities and tools (ranging from symbol systems to artifacts to language) are regarded as integral to conceptual development” (p.348). The notion of learning being intrinsic or coming from within was a central tenant of John Dewey’s essay, *The Child and the Curriculum*. In his essay, Dewey (1902), states “Learning is active. Involves reaching out of the mind. It involves organic assimilation from within” (p.7). Equally important, constructivism focuses on an individual’s concept development and deep understanding (Twomey Fosnot & Perry, 1996).

**Social Constructivism**

Social constructivism is based largely on the work of (Berger & Luckmann, 1966) and later the writing of (Lincoln & Guba, 1985). The philosophical viewpoint of social constructivism is that individuals develop their own subjective meanings of their experiences as these relate to objects or things (Creswell, 2013). In social constructivism, the process of constructing meaning is individual and embedded within the particular social setting of which an individual is a member (Berger & Luckmann, 1966; Creswell, 2013; Duit & Treagust, 1998).
Knowledge therefore, is distributed and created socially. Berger and Luckmann (1966) describe the distribution of social knowledge as “the social distribution of knowledge thus begins with the simple fact that I do not know everything known to my fellowmen, and vice versa, and culminates in exceedingly complex and esoteric systems of expertise” (p.46). Crotty (1998) identifies three key components: meanings are constructed by humans, humans engage with their world and make sense of it based on historical, social and cultural perspectives, and the basic generation of meaning is always social.

In this study, the participants are embedded members of a fellowship and the PLCs in which they work offer unique opportunities for participants to socially engage with their peers and construct new or better understandings of their shared practice. The participants in this program constantly reflected on their experiences, both individually and collaboratively - asking new questions and generating shared beliefs and understandings. The scientific knowledge of teachers and students is symbolic and socially negotiated (Driver, Asoko, Leach, Scott, & Mortimer, 1994) and in this study participants knowledge was socially shared and generated. Additionally, science is understood to be both personally and socially constructed (Millar & Driver, 1987). Therefore, the theoretical framework of social constructivism fits this study very well.
Chapter III

METHODS

Research Design

Qualitative research has its origins in the descriptive works of Greek scholars such as Herodotus who was active during the 5\textsuperscript{th} century B.C.E. and Sextus Empiricus who was active during the 2\textsuperscript{nd} Century C.E. Many of the descriptive texts of Aristotle and Galen can also be considered to be qualitative in nature (Erickson, 2011). Today, qualitative research is known as a mode of research that incorporates deep, descriptive accounts of individuals or groups of individuals and the actions they take in their everyday lives (Merriam, 2009). More than this, qualitative research as a methodology, aims to develop understandings of why actions are carried out and what they mean to the various individuals or groups. Creswell (2013) describes qualitative research as “a means for exploring and understanding the meaning of individuals or groups ascribe to a social condition or human problem” (p.4). In this study, I wanted to learn more about the experience of elementary teachers engaged in vertically aligned professional learning communities [V-PLCs] that were part of a bigger two-year program of intensive professional development [PD] for K-12 science teachers. Because of the descriptive nature of qualitative methodology and its underlying aim of developing increased
understandings of the experiences from the perspective of the participants, I chose to use qualitative methodology for my research.

The exploratory case study approach (Yin, 2013) was utilized to develop an understanding of how V-PLCs provide a context for support and growth in 28 participating elementary science teachers. Crotty (1998) notes that the case study methodology is well-aligned with a constructivist theoretical framework. Case studies result in a rich description of themes emerging from the data sources and seek to bring together research participants into a bounded system with multiple sources of information for the sake of better understanding their experiences and perspectives (Creswell, 2013; Denzin & Lincoln, 2005; Merriam, 1998).

For this study, the bounded system included the 60 (K-12) science teachers participating in the first year of the program. The 28 elementary teachers in the program were considered as the case for analysis. The data from these 28 elementary teachers was analyzed for insights about the case (Merriam, 1998). Each of the 28 participants is an elementary science teacher from one of five diverse, high-needs districts in the vicinity of a large metropolitan area. These teachers are selected by the program to be fellows for two years. The fellows have varying levels of experience with varied range in science expertise, science content area expertise and grade level (K-12).

**Setting and Participants**

The science teachers who were participants in this study were engaged in a two-year science education fellowship program. In order to become a member of this program, teachers underwent a rigorous application process. If selected, the teachers
became science education fellows and in this study are known henceforth as fellows. The fellows underwent two years of intensive support. During year one, fellows received monthly professional development at the university site and worked for the first half of the year in vertically aligned professional learning communities (V-PLCs) and the second half of the year in horizontally aligned professional learning communities (H-PLCs). These V and H-PLCs were created by the university leadership team, which comprised myself and two professors at the university site. The V-PLCs were created using a common subject area for middle and high school fellows and the subject area preference of the elementary fellows. Thus, there were four different V-PLCs: biology, chemistry, earth science, and physics. In each of these V-PLCs there was a mix of fellows including representatives from high school, middle school and elementary school. The H-PLC varies in the make-up of fellows, and in these PLCs the fellows were grouped by similar grand bands and across different content areas. In the V and H-PLCs, teachers were required to observe and reflect with their peers on their teaching. During year two of the fellowship, fellows designed, enacted, and reported on a personal project in their classroom or school district. There were three cohorts of fellows each cohort containing 20 fellows. In this study, the participants were members of the larger fellowship totaling 60 science education fellows from elementary, middle and high schools located in five high needs school districts in a local geographic region located in the north-eastern United States. For this study, I examined the individual and shared experiences of the 28 practicing elementary science fellows who participated in the program. Specifically, I examined these elementary fellows experiences from the V-PLC component of the program.
**Elementary fellows.** Amongst the 28 elementary fellows there were a wide variety of experience. The breakdown of the elementary fellow participants is shown in Table 3.1 along with the grade they were teaching during the study and their gender.

Table 3.1: Elementary Fellows by Experience, Grade Taught and Gender.

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Pseudonym</th>
<th>Years Teaching</th>
<th>Grade Level</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Marcia</td>
<td>18</td>
<td>6th</td>
<td>Female</td>
</tr>
<tr>
<td>1</td>
<td>Kathy</td>
<td>13</td>
<td>4th/5th</td>
<td>Female</td>
</tr>
<tr>
<td>1</td>
<td>Lorraine</td>
<td>18</td>
<td>2nd,5th</td>
<td>Female</td>
</tr>
<tr>
<td>1</td>
<td>Grace</td>
<td>11</td>
<td>5th</td>
<td>Female</td>
</tr>
<tr>
<td>1</td>
<td>Ethan</td>
<td>10</td>
<td>3rd</td>
<td>Male</td>
</tr>
<tr>
<td>1</td>
<td>Zoe</td>
<td>19</td>
<td>K-5th</td>
<td>Female</td>
</tr>
<tr>
<td>1</td>
<td>Peyton</td>
<td>12</td>
<td>1st,2nd,4th</td>
<td>Female</td>
</tr>
<tr>
<td>1</td>
<td>Caleb</td>
<td>23</td>
<td>5th</td>
<td>Male</td>
</tr>
<tr>
<td>2</td>
<td>Piper</td>
<td>20</td>
<td>2nd</td>
<td>Female</td>
</tr>
<tr>
<td>2</td>
<td>Lily</td>
<td>20</td>
<td>6th</td>
<td>Female</td>
</tr>
<tr>
<td>2</td>
<td>Althea</td>
<td>15</td>
<td>2nd</td>
<td>Female</td>
</tr>
<tr>
<td>2</td>
<td>Leona</td>
<td>21</td>
<td>K-6th</td>
<td>Female</td>
</tr>
<tr>
<td>2</td>
<td>Penelope</td>
<td>14</td>
<td>3rd - 4th</td>
<td>Female</td>
</tr>
<tr>
<td>2</td>
<td>Gabriella</td>
<td>10</td>
<td>4th</td>
<td>Female</td>
</tr>
<tr>
<td>2</td>
<td>Faith</td>
<td>5</td>
<td>4th</td>
<td>Female</td>
</tr>
<tr>
<td>2</td>
<td>Stella</td>
<td>22</td>
<td>K</td>
<td>Female</td>
</tr>
<tr>
<td>3</td>
<td>Cecilia</td>
<td>30</td>
<td>2nd – 5th</td>
<td>Female</td>
</tr>
<tr>
<td>3</td>
<td>Bella</td>
<td>31</td>
<td>4th and 5th</td>
<td>Female</td>
</tr>
<tr>
<td>3</td>
<td>Arianna</td>
<td>17</td>
<td>2nd</td>
<td>Female</td>
</tr>
<tr>
<td>3</td>
<td>Ella</td>
<td>16</td>
<td>K-5th</td>
<td>Female</td>
</tr>
<tr>
<td>3</td>
<td>Harper</td>
<td>17</td>
<td>K-2nd</td>
<td>Female</td>
</tr>
<tr>
<td>3</td>
<td>Kaylee</td>
<td>16</td>
<td>1st</td>
<td>Female</td>
</tr>
<tr>
<td>3</td>
<td>Kylie</td>
<td>17</td>
<td>6th</td>
<td>Female</td>
</tr>
<tr>
<td>3</td>
<td>Mackenzie</td>
<td>15</td>
<td>2nd</td>
<td>Female</td>
</tr>
<tr>
<td>3</td>
<td>Olivia</td>
<td>16</td>
<td>2nd – 5th</td>
<td>Female</td>
</tr>
<tr>
<td>3</td>
<td>Julia</td>
<td>13</td>
<td>2nd</td>
<td>Female</td>
</tr>
<tr>
<td>3</td>
<td>Abigail</td>
<td>4</td>
<td>K</td>
<td>Female</td>
</tr>
</tbody>
</table>

**First year fellows.** During year one of the program, fellows participated in monthly professional development sessions and extensive group work with one another to analyze their own teaching and that of their colleagues in the program. During year
one of the fellowship, participants met with the leadership team at a university site once a month to receive professional development and support for the independent work that was carried out in small professional learning communities. These participants interacted with one another and socially created understandings of their own teaching practice and vertical and horizontal connectedness in science learning as it related to their classroom through interactions with peers in the program.

**Vertically aligned professional learning communities.** In the first half of year one, fellows were organized into V-PLC teams consisting of three to five fellows. The V-PLCs were deliberately constructed by the leadership around a content area (earth science, biology, chemistry or physics) and included fellows from each of the grade level groupings (K-5, 6-8, and 9-12). The last cohort, cohort 3, proved tricky to organize in the exact way that cohort 1 and 2 had been organized. This was principally due to the shortage of middle school teachers for the final cohort of the fellowship. In light of this issue, the leadership team organized cohort 3 with two biology content groups and with several PLCs lacking middle school representation. While this was far from the ideal, it did allow for a vertical experience for all fellows in cohort 3, albeit with less diversity of classroom observations.

The university leadership team used several measures to place fellows in their V-PLCs. Both high school and middle school fellows were placed using their area of certification and what they currently teach. Next, the elementary teachers were divided amongst the V-PLCs by their subject area of preference. Elementary teachers indicated their subject area of preference on their initial application and then ranked the other
subject areas in order of preference. The vertically aligned groups that were established can be seen arranged by cohort in Table 3.2.

Table 3.2: V-PLC Members by School Level, Subject Area and Cohort

<table>
<thead>
<tr>
<th>Cohort</th>
<th>School Level</th>
<th>Biology</th>
<th>Chemistry</th>
<th>Earth Science</th>
<th>Physics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Elementary</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>Middle</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>High</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Elementary</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Middle</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>High</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Elementary</td>
<td>Bio I</td>
<td>Bio II</td>
<td>Earth Science</td>
<td>Physics</td>
</tr>
<tr>
<td>3</td>
<td>Middle</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>High</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Once assigned the members of each V-PLC were directed to mutually decide upon a ‘course of study’ (COS), in which to ground their work, e.g., inquiry or using technology, and also identified a specific content topic identified from the Next Generation Science Standards (NGSS) within their subject specialty, e.g., plate tectonics, photosynthesis, etc. Fellows took turns to video their teaching in their individual classroom and then shared this video with their V-PLC peers on a password protected system. After all the V-PLC members have watched the video they met either in person, or remotely for a group debriefing session. This debriefing session was video recorded. During the debriefing session, the V-PLCs followed an extensive debrief protocol known as the Collaborative Coaching and Learning in Science Model originally developed by the Boston science partnership. This debriefing protocol included multiple opportunities for group and individual reflection. Debrief forms pertaining to this can be found in the Appendix A.
Data Sources and Collection

Because the fellowship created such a uniquely defined group of teachers, case study provides a solid methodology for data collection. For this study, a variety of data sources were collected and analyzed. These included monthly fellow reflections, written feedback from fellows, and fellow notes from V-PLC and H-PLC meetings. According to Merriam (2009), “documents are a ready-made source of data that are not influenced by the presence of a researcher, nor dependent on the cooperation of an individual which is as such a necessity during interview or observation” (p.155). Table 3.3 shows the actions of fellows and the leadership team each year of the fellowship and the data sources available from these actions. Detailed descriptions follow for each of the data sources that were utilized to study the experiences of the elementary fellows.

Table 3.3 – Year One and Post-Fellowship Activities and Data Sources

<table>
<thead>
<tr>
<th>Professional Development (Leadership Team Directed)</th>
<th>Fellows Independent and Group Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activities</td>
<td>Data Sources</td>
</tr>
<tr>
<td>-Monthly Meetings</td>
<td>-Fellow communications</td>
</tr>
<tr>
<td>-End of PLC presentations</td>
<td>-Researcher notes</td>
</tr>
<tr>
<td>-Annual tri-site conference</td>
<td>-Fellow presentations</td>
</tr>
</tbody>
</table>

Post Fellowship

<table>
<thead>
<tr>
<th>Data Sources</th>
<th>Fellows Independent and Group Work</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-Fellow communications</td>
</tr>
</tbody>
</table>

Monthly fellow reflections. Each month fellows were required to reflect on the material with which they had engaged during the monthly professional development meeting. A list of the reflection prompts can be found in the Appendix B. Monthly topics
included assessment, NGSS, presentation skills, action research, and more. In addition, fellows reflected on such items as their personal growth, interactions in vertically aligned teams, and other professional concerns and thoughts that they wished to record. The monthly reflection documents provided fellows with a record of their growth and learning over the period of the fellowship. Additionally, these monthly reflections allowed the fellowship leadership team to identify topics, areas of interest, or concerns held by the fellows that could be addressed in future professional development sessions. These reflections were written in Google documents and shared with the leadership team. The leadership team compiled the reflections into electronic files and organized the reflections by month, V-PLC, and fellow.

**Videos of fellows teaching and debriefing.** As part of the fellowship program, each fellow received a video camera to record their teaching so that they could share their work with their peers for constructive feedback and insight. During the V-PLC period (first half of year one), each fellow was required to record one full class period and share this with their V-PLC team. The video recordings were shared via a password protected platform and individuals were able to view their team members’ recording. The video-sharing aspect of the fellowship was critical because it allowed fellows the opportunity to observe teaching in other science classrooms asynchronously, without the logistical and administrative complications of physically observing other classes. Fellows were able to observe other science teachers in action across grade levels K-12 and in several districts outside of their own; therefore, fellows were exposed to a wide range of teaching ability, contexts, and science content teaching.
Written debrief notes of group meetings. Each video recording of a lesson was watched by the V-PLC team and the team then met and provided feedback to the fellow. During these meetings, the feedback and interactions of the team were video recorded, and fellows individually used a pre-designated written protocol (Appendix B) to record their own feedback and reflections during the meeting. These personal written documents provided valuable insight into individual fellow perspectives during the video debrief sessions. These documents allowed the researcher to triangulate findings from other data sources by complementing or solidifying perspectives offered during the video recorded debrief sessions.

Field notes from interviews, professional development sessions and other interactions. As a teacher researcher, in the fellowship involved leading professional development sessions and supporting fellows throughout the two-year program. In this role, as a researcher, I noted key observations during the professional development sessions, including fellow reactions, key points raised, and notable fellow-fellow, fellow-coordinator, or fellow-facilitator interactions, and recorded my observations at various stages throughout the study. Merriam (1998) makes reference to the importance of field notes, “Observations must be recorded in as much detail as possible to form the database for analysis” (p. 111). These notes provided an important opportunity for triangulation of findings in the post-fellowship survey, other data sources and confirmation of ideas found, for instance, in the video recorded peer-peer debriefing session and the peer-peer feedback provide during monthly professional development. It is important to note that as a leader of the fellowship program and the researcher, I had “insider status,” allowing me to be a “researcher teacher” while both leading and studying the professional
development experience of participants (Roth, 2007, p.1210). The intimate knowledge gained through this relationship, along with the “long-term observation” (Merriam, 1998, p. 204) of participants during the two-year fellowship provided elements of a rigorous study throughout the data collection and the data analysis process.

**Post fellowship survey.** Elementary fellows received a post-fellowship survey which asked them to identify their experiences in the fellowship using question prompts to write short reflections. The post-fellowship survey prompts are listed in Appendix D.

**Data Analysis**

This study was an exploratory case study (Yin, 2013). The first step I took was to carefully review all the data produced by all 60 fellows, with an emphasis on the 28 elementary fellows comprising the case and take note on points of interest, potential similarities, and differences between these individuals. I took careful notes on these initial observations. Following this, I ended up with multiple units of data. Lincoln and Guba (1985) state that units of data must meet two criteria. The unit must be heuristic or should reveal something relevant to the researcher about the study and the unit should be the smallest amount of data that could stand by itself. These units were items of data that stood out to me as being important for my study, and they represented two kinds of events or occurrences in the data that I had identified either from individual elementary fellows, or from multiple elementary fellows or V-PLC debrief meetings. This examination was approached from learning more about the individual elementary fellow’s experience as they participated in a V-PLC, and so the units of data identified
from individual or group contexts were deemed to be of equal importance for this goal. For example, in some cases, it is important to focus on what the upper level fellows in the V-PLC debrief say, as this impacts the elementary fellows. Likewise, there were also examples where it was important to focus on what an elementary fellow said to an upper level peer, as this also provided important descriptive information about the elementary fellow.

Next, I took each of the data units generated and sorted through them across the units using the constant comparative method (Glaser, 1965). This method of analysis was deemed appropriate because the purpose of the initial sorting was inductive and comparative and could be used without the goal of developing a grounded theory (Merriam, 2009). As I went through the units of data using the constant comparison method, I used open coding to identify common themes between units and placed units with similar themes into categories. At this point of my data analysis I began to develop several clear groups of units which provided useful insight for examining the experiences of elementary fellows during the V-PLC component of the program. It is important for the descriptive analysis that I acknowledge that the program as a whole comprises three cohorts each made up of 20 K-12 science teachers. The participation of each cohort lasts for two-years and is staggered across a five-year duration. The participants in the case study, the 28 elementary fellows worked in the program with their K-12 peers and at certain points of the data analysis, I felt that it added to the strength of the descriptions to include data from middle and high school fellows that supported or furthered understandings about the experiences of the elementary fellows.
Several videos of fellow meetings and debriefing sessions were also transcribed for analysis. Specifically, these transcriptions were analyzed to gain a better understanding of context and perspectives of teachers working in each of the V-PLC teams as they related to professional practice. The examination and transcription of video debrief sessions was not all inclusive, however. Using purposeful sampling (Creswell, 2013), I restricted the sample to only include the debriefing sessions of several elementary level fellows. The overall purpose of the data set in this study was to achieve what Creswell (2013) describes as “maximum variation” and Kleining and Witt (2000) describe as “the paradigm of maximal structural variation of perspectives” (p.4). As such, as the researcher, I decided it was not necessary to examine all of the video debrief recordings in order to represent the diversity present in the fellows and the variation of the many different contexts and perspectives present amongst the fellows.

During the next phase of my analysis, I looked across the themes that I had established using open coding and I began to collapse themes that shared many similarities, or that could be classified under a broader and larger theme. This process followed the guidelines of axial coding (Corbin & Strauss, 2008). The themes were then further “fleshed out” (Merriam, 2009, p. 182) by several more examinations of the data as a whole. During these tertiary and quaternary examinations of the data, I looked for more supporting data and details of the context of certain data units so as to be able to provide more evidence and detail to support each theme. The final categories and themes within each are identified in Table 3.4:
Table 3.4: Coding Units by Category and Theme.

<table>
<thead>
<tr>
<th>Category</th>
<th>Themes within Category</th>
<th>Occurrences</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Positive support structure for personal and professional growth?</strong></td>
<td>Positive V-PLC Reflections</td>
<td>120</td>
</tr>
<tr>
<td>Development of pedagogical skills and content knowledge?</td>
<td>K-12 Scientific Language</td>
<td>86</td>
</tr>
<tr>
<td></td>
<td>References to Misconceptions</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>ELA and Science Connection/References to Literacy and General Language</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>Using Feedback and/or Assessment to Guide/Impact Lesson</td>
<td>30</td>
</tr>
<tr>
<td>Improving student success in the elementary science classroom</td>
<td>Identifying Student Success</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Student Understanding</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>Thinking, Reasoning and Questioning in the Science Classroom</td>
<td>134</td>
</tr>
<tr>
<td>Total Coding Units</td>
<td></td>
<td>527</td>
</tr>
</tbody>
</table>

**Validity and Rigor**

Using multiple data sources increases trustworthiness in qualitative findings and leads to richer description of the inquiry (Creswell, 2013). Additionally, using a wide variety of documents, such as those used in this study provides several advantages. First, the data can be considered objective and a direct product of the context of the study; consequently, data is unadulterated by the researcher. Second, Merriam (2009) stated, “documents exist independently of the research agenda” (p.155), and thus, documents fit the heuristic methodology well, allowing for the emergence of themes to occur through the “discovery of similarities” (Kleining & Witt, 2000, p3). In order to ensure trustworthiness of the findings as the researcher, I analyzed the data by looking at many
different sources created by different participants. Each of these different sources of data were taken from different contexts within the program, for example, written notes on a lesson video, personal reflection journals and a video of a debrief. By using such a variety of sources for the data, I was able to achieve a view of the elementary fellow experiences which offered a variety of perspectives. This kind of data analysis is identified by the authors Kleining and Witt (2000) as being a paradigm of maximal structural variation of perspectives. This variation is reflected in the data sources, participants, and situations in which the data was collected.

The variety of data and the amount of time spent involved in the field (fellowship) are both characteristics of a rigorous qualitative study (Creswell, 2007). The variety of data also permitted triangulation (Denzin, 1970). Denzin explains four types of triangulation and their combination. In this study, “methodological triangulation” and “data triangulation” (Denzin, 1970, p. 472) were employed by using different types of data over time that occurred within different contexts, such as written reflections after a debrief, notes made during an observation of a peers teaching, observations recorded by the researcher watching video of a debrief session, or verbal feedback provided from a fellow to a peer, etc., to increase the rigor and validity.

Other elements of rigor employed by this study were “peer examination,” where findings were discussed with a colleague or colleagues (the leadership team and dissertation committee) as they emerged. Using multiple layers of coding and making many passes of the data are also elements that represented rigorous qualitative research (Creswell, 2007).
While true generalizability is much sought-after and may be considered by some fields to be the gold standard for validity, it is a very difficult characteristic to achieve in qualitative research designs, such as this study, because generalizations that are context free have very little use when describing human behavior (Guba & Lincoln, 1981). Nonetheless, this research uses rich, thick description and multiple case studies to present the findings so that the reader may gain deep familiarity and perhaps come to see parallels that may be applicable in similar situations (Merriam, 1998)

**Role of the Researcher**

As part of my role in this study, I have worked closely with the participants over a two-year period. During that time, I acted as a member of the leadership team, supporting participants as they progressed through the fellowship. During my analysis of the data, I concisely and deliberately examined data sources from my perspective as a researcher. However, it is important to acknowledge that my familiarity with the participants does impact my analysis. I am able to use background knowledge of both the individual participants and the context in which they are working to provide a more in depth understanding of situations and interactions.

In the next three chapters (Chapters IV, V, and VI), I present the findings of the study. These three chapters are considered to be stand-alone papers that focus on the learning elementary teachers gain from participating in vertically-aligned professional development.
Chapter IV

FINDINGS

VERTICALLY ALIGNED PROFESSIONAL LEARNING COMMUNITIES FOR ELEMENTARY SCIENCE TEACHER GROWTH TO SUPPORT STUDENT SUCCESS

Abstract

The Next Generation Science Standards (NGSS) are being implemented in many states including the state in which this study was based. Unfortunately, there exists a potentially fatal flaw that will negate the impact of NGSS implementation, namely the expectation that elementary science instruction will provide a grounding for all future science learning in a student’s school journey. This study sets out to investigate the experience of elementary science teachers involved in a fellowship and working in a vertically aligned professional learning community (V-PLC) that comprises K-12 science teachers. This study explores the benefits of these communities and identifies several important findings that demonstrate the power of these V-PLCs for supporting the growth and development of elementary science teacher knowledge in supporting student success in science. Additionally, several benefits identified show how these V-PLCs could support elementary teacher growth and development in the kind of science teaching and student experiences envisioned in the NGSS.
Keywords:
Elementary Science Teaching / Vertically Aligned Professional Learning Community

Introduction

The shortcoming in most elementary schools is the ability of elementary teachers to teach high quality NGSS aligned science lessons. The literature shows us that elementary teachers are poorly prepared for teaching science, struggle to find time in the week for teaching science, feel intimidated at the prospect of teaching science, and actively avoid teaching science. For example, elementary teachers have traditionally been prepared as generalist educators (Kier and Lee, 2017) with very little focus, if any, on science teaching during their teacher coursework (Appleton & Kindt, 1999). In addition to this, many elementary teacher candidates and practicing elementary teachers have an inadequate academic background for teaching science (Lee et al., 2008; Tilgner, 1990; Tosun, 2000;). The combination of poor preparation for teaching science and an insufficient academic background in science result in a dearth of confidence and desire for teaching science at the elementary level (Abell & Roth, 1992; Appleton, 2013; Avraamidou, 2013; Gunning & Mensah, 2011).

While there is significant concern about the preparation and suitability of elementary teachers to teach science, there is also wide-ranging concern about district and government policy that has focused on ELA and Math above all else. Often district and government policies have had a direct, detrimental effect on science in elementary school (Blank, 2012; Buczynski & Hansen, 2010; Mensah, 2010). Such shortsighted policy
decisions and business as usual teacher preparation programs have resulted in national concern at the state of elementary science teaching in the United States (Olson, Tippett, Milford, Ohana, & Clough, 2015).

**Professional Development**

According to Wilson (2013, p. 310), “the U.S. PD [professional development] system is a carnival of options.” Reiser (2013) suggests that professional development for science teachers must become far more consistent and address areas in meaningful and focused ways. Reiser also includes the following key components for successful NGSS PD for currently practicing teachers. PD must be: (a) deeply embedded in subject matter; (b) designed to involve active learning; (c) able to connect teachers to their own practice; and (d) part of a coherent system of support. Effective professional development (PD) must be deeply embedded in the content (Banilower, Heck, & Weiss, 2007; Cohen, 1990; Garet, Porter, Desimone, Birman, & Yoon, 2001), designed to involve active learning (Banilower et al., 2007; Mundry & Loucks-Horsley, 1999), able to connect teachers’ to their own practice (Fullan, 2007; Loucks-Horsley & Matsumoto, 1999), and part of a coherent system of support (Reiser, 2013). Additionally, effective PD needs to occur over a sustained period of time (Crawford et al., 2014; Sandholtz & Ringstaff, 2016).

In a study of 1027 science and math teachers, Garet et al., (2001), identified a positive relationship between active learning and correlation. Active learning refers to the process of learning that a teacher undergoes when they are able to take time to plan, implement, engage with students, reflect, assess student learning and share their work
with others. Correlation describes the way in which a teacher has time to connect their work to their goals, experiences, alignment to standards and professional communication/collaboration with their colleagues (Garet et al., 2001). In the same study of 1027 science and math teachers, content focus and coherence were also shown to have a positive impact on teacher knowledge and skills over time (Garet et al., 2001). In this study, the model of being studies consists of a professional learning community (PLC) and the protocols and procedures that participants follow are in line with the findings of Garet et al., (2001). Participants are provided the opportunity to observe peers teaching using video and reflect and provide feedback in a collaborative knowledge building focused environment.

We know that PD which involves teachers as active participants and provides them the ability to take control of their own learning (Dori & Herscovitz, 2005), permits teachers to spend positioning new methods or practices in their individual classroom context (Van Der Valk & De Jong, 2009). The PLC in this study is designed to allow teachers to take control of their own learning and provides times for them to use their new knowledge in their classrooms, and to reflect and discuss their experiences with peers.

**Professional Learning Communities**

Professional learning communities or PLCs emerged in the latter half of the 1980s, originally being termed “learning communities” (Hord, 1997). The concept of the learning community originates from the business domain, where there was an increasing need within organizations to share, develop and nurture professional knowledge, also
known as human capital, in an attempt to promote the building of knowledge, leadership and innovation from within organizations. Learning communities are defined as groups of people that act on an ongoing basis to develop their knowledge of a common interest or passion by sharing individual resources and by engaging in critical dialogue (Wenger, McDermott, & Snyder, 2002).

Hord’s commonly used definition describes PLCs as a community of “Five Dimensions.” These are 1) supportive, shared leadership, 2) collaborative learning with a student needs focus, 3) shared vision and values focused on student learning, 4) supportive structural and interpersonal conditions, and 5) shared practice. (Hord, 1997; Hord & Sommers, 2008). While PLCs are enthusiastically acknowledged as important for encouraging and supporting professional growth amongst teachers, there is a lack of knowledge in the literature about how PLCs are developed and sustained (Dooner, Mandzuk, & Clifton, 2008; Jones, Gardner, Robertson, & Robert, 2013; Tichnor-Wagner, Harrison, & Cohen-Vogel, 2016).

**Supporting Student Success in the Science Classroom**

In the last two decades or so, much has changed in our knowledge of what we now know about the potential for sophisticated reasoning and scientific activities that elementary students can undertake and master in the science classroom (Lehrer & Schauble, 2004, 2006; Magnusson & Palincsar, 2005; Windschitl & Calabrese Barton, 2016). However, in many science classrooms, the teaching that occurs is often based on traditional methods and lacks any significant attempt to support students in the development of connections between the classroom ‘activities’ and scientific practices or
ideas (Abrahams & Reiss, 2012; Ogborn, Kress, & Martins, 1996; Pardo & Parker, 2010), student objectives are often low level and mismatched to instruction (Corcoran & Gerry, 2011; Good & Lavigne, 2017), the actual lesson activities conducted in science classrooms tend to be procedural in nature (Banilower et al., 2013; Kang, Windschitl, Stroupe, & Thompson, 2016; Roth, 2014; Roth & Garnier, 2007), and there is often little to no attempt to support or develop student reasoning and/or understanding (Osborne & Dillon, 2008; Rennie, Goodrum, & Hackling, 2001; Windschitl & Calabrese Barton, 2016).

Another area of concern in science teaching in the United States is that of questioning. Studies by Weiss, Pasley, Smith, Banilower, and Heck (2003) and (Bowes & Banilower, 2004) both show that many elementary science teachers either do not ask students questions in their lessons, ask very low level or closed questions, or ask questions that do not provide opportunities for student to develop or deepen their understanding.

Supporting student success relies on a teacher’s ability to engage with the curriculum and design instruction that will support and build on student’s prior knowledge. One of the issues spoken to previously in this literature review addresses the historical basis for the problems which are present in the elementary science classroom today. Although many researchers have examined how to support middle and high school teachers in developing instruction more in line with that called for in NGSS, there are few studies that look at the issues practicing elementary teachers face.

To get an idea of what research is out there, a comprehensive search of the literature was carried out from 2014 to the present to identify peer reviewed articles that
addressed the issue of supporting elementary science teachers with NGSS implementation. For example, 234 articles were identified and reviewed from the major science education journals and other appropriate journal sources, and 132 articles were deemed inappropriate for this review because the study was based in a middle or high school setting. 63 articles were also eliminated because the study focus was preparing pre-service elementary science teachers. Some of these studies which examine pre-service elementary school teachers do discuss how to support their engagement with the NGSS, but these do not provide any useful or transferable knowledge that we may use to promote growth amongst currently practicing elementary teachers.

One article on pre-service elementary science teachers that does provide some relevant data is by Hanuscin and Zangori (2016). The authors describe a pre-service elementary program designed to increase pre-service elementary teachers’ practical knowledge of the NGSS. The authors describe that limitations to this study include the amount of pre-existing science content knowledge a pre-service teacher elementary has. The participants in my study are practicing elementary teachers, yet, like the pre-service teachers in the Hanuscin and Zangori study, they too are hampered by limited exposure to science content. One potential benefit to V-PLCs [vertically aligned professional communities] might be that practicing elementary teachers are exposed to more science content by observing teaching and interacting with peers from both the middle and high school level.

Of the remaining 39 articles, there were nine rough categories. These categories were articles that addressed the following: Literacy; Access, power and diversity; Scientific agency or identity; Aligning curriculum to NGSS; Science teaching practices;
Instructional materials (including textbooks); Professional development; Scientific argumentation or explanations; Teaching engineering.

American elementary science classrooms have many difficulties associated with implementing teaching practices that support student development and understanding of scientific ideas and thought processes. This study aims to investigate how a professional space (professional learning community) designed to encourage supportive reflection and professional dialogue amongst science teachers might permit the sharing and building of knowledge about the ways a teacher may best support their students’ success in science, which in turn may help realign the teachers practice to support teaching more in line with what the NGSS envisions.

**Purpose of the Study and Research Question**

With NGSS adaptation, there is an urgent need to support K-12 science teachers as they adopt and implement the three core constructs; disciplinary core ideas, cross cutting themes and science and engineering practices, into their science teaching. More than this however, K-12 science teachers need to be supported to develop a view of science curriculum that accommodates a K-12 journey of scientific knowledge development within their respective students. Knowing about the vertical nature of this knowledge development as laid out in the NGSS will enable all teachers on the K-12 continuum to understand their role in the bigger picture of student success over a student’s school experience. We know that elementary teachers are often poorly prepared to teach science and would often prefer not to teach science because of this lack of preparation. Additionally, educational policies of the last 17 years have resulted in a
significant reduction in the amount of time science is taught at the elementary level. This study aims to explore how elementary science teachers are impacted when they engage in a professional development that is deeply embedded in content, based in the practice of science teaching, involves active learning and creates a supportive structure in which all participants can learn and grow. Professional learning communities [PLCs] seem well placed to support such knowledge development and growth. PLCs provide a supportive social environment and allow the opportunity for teachers to create a community with peers who share the practice of science teaching. This study examines practicing elementary science teachers and their learning in a vertically aligned professional learning community.

**Research Question**

How does participation in a vertically-aligned professional learning community support elementary teachers’ growth and knowledge development in supporting student success in the elementary science classroom?

**Methodology**

This study occurred within a two-year program for K-12 science teachers. Teachers apply to this program and undergo a rigorous selection process. If selected, they become known as science education fellows which henceforth I shorten to fellows. During year one of the program, fellows undertake monthly PD [professional development] meetings with a university-based leadership team. The university-based
leadership team includes two professors and myself. Also, in the first year, fellows work in professional learning communities [PLCs]. During the first half of year one, the fellows work in vertically aligned PLCs (V-PLCs) and in the second half of year one, the fellows work in horizontally aligned PLCs (H-PLCs). During the second year, fellows work on individual projects known as a growth plan system. There are three cohorts of fellows, each cohort containing 20 K-12 teachers. The cohorts complete the program one year apart. In total there are 60 fellows who participated in the program. These fellows were selected from five high-needs school districts in the geographical region of the university site. The 60 fellows are split between the three grade bands, elementary, middle and high. This study examines the experiences of the elementary fellows in the V-PLC component of the first year only. However, there are some data from middle and high school fellows included in the findings, because these data either provide context or narrative for the findings, or provide interesting or unique evidence to show the variety of voices and perspectives that elementary fellows are exposed to during participation in a V-PLC.

During the V-PLC phase each fellow works in a small group of between four or five fellows. The fellows in this groups represent the three grand bands. Middle and high school V-PLC members are selected by the university leadership team based on the content specialty recorded on their teaching license. The elementary fellows are assigned to the various content areas based on a preference indicated on their application. In each cohort there are usually 4 V-PLCs, in the areas of biology, chemistry, earth science, or physics.
Once assigned to a V-PLC, fellows work together to decide on an area of content that they wish to focus on as a group. For example, one chemistry V-PLC focused on states of matter. Each V-PLC must also mutually agree upon a research topic that they will all incorporate into their teaching. Examples of the types of research areas that were picked include one V-PLC who chose to focus on outdoor education, and another V-PLC who chose to focus on incorporating technology in the science classroom.

When the content and research focus had been decided on, the fellows then take turns to video record a lesson of themselves teaching. This video is then shared on a password protected platform and the other members of their V-PLC observe the video. Once all the team have observed a lesson video, a mutually agreeable time was decided on for a V-PLC debrief. During this debrief a strict protocol (Appendix B) is followed and each fellow has documentation to complete that facilitates recording of their own responses and those of their peers. Each debrief session is also recorded by the V-PLC and this video is also shared onto the password protected platform.

Data from written documentation of 60 V-PLC debriefs, personal reflection journals for the 28 elementary teacher fellows and select video data from debrief meetings were analyzed using open and axial coding, to identify emergent themes and unique occurrences during the V-PLC phase of the fellowship. The methodology of exploratory case study (Yin, 2013) was used. The program as a whole was considered as the bounded case. Fellows were bounded by the context they shared in participating in the two-year program. They experienced the same processes throughout this time. The bounded case is especially interesting, because for the first time within the literature, a vertical alignment is used to provide a supportive social structure that aims to facilitate
the building of knowledge of practice and personal development in science teaching amongst elementary teachers.

Each fellow’s data was examined individually, notes were made and codes were assigned to observations. The codes and notes from each individual case were then examined and compared across all the other cases. Themes and occurrences were identified, and these findings are reported in the following section. Using multiple layers of coding and making many passes of the data are elements that represent rigorous qualitative research (Creswell, 2007). In addition, in order to ensure trustworthiness of the findings as the researcher, I analyzed the data by looking at many different sources created by different participants. Each of these different sources of data were taken from different contexts within the program, for example, written notes on a lesson video, personal reflection journals and a video of a debrief. By using a variety of sources for the data, I was able to achieve a view of the elementary fellow experiences which offered a variety of perspectives. This kind of data analysis is identified by the authors Kleining and Witt (2000, p.4) as being a paradigm of maximal structural variation of perspectives.

The variety of data permitted “methodological triangulation” and “data triangulation” (Denzin, 1970, p. 472). This approach served to increase the rigor and validity. The findings in this study use rich, thick description and multiple examples to present the findings so that the reader may gain deeper understanding and perhaps come to see parallels that could be applicable in similar situations (Merriam, 1998).
Findings

In this section, I present the three main themes which emerged during data analysis. These were: a) identifying student success, b) student understanding, thinking, reasoning, and c) questioning in the science classroom. For each theme I provide a description of the theme and present artifacts from the data that support the theme. Each theme is followed by a brief summary of the findings within the theme.

**Theme 1: Identifying Student Success**

In the data, there were many examples of fellows providing encouraging feedback to one another when they observed their peers effectively supporting student success. A total of 35 coding occurrences were observed for this theme. For example, during one debrief, Zoe, an elementary fellow from cohort 1, provided the following feedback to Sarah, a high school fellow:

> I was able to see evidence of student learning during the observation when students readily shared evidence of Wegener’s Theory of Continental Drift. They were able to construct Pangea and included information from the readings. (Zoe, Elementary Teacher, Cohort 1)

Another elementary fellow, Ethan, who was in the same V-PLC, also identified to Sarah that he witnessed evidence of student success during his observation of her lesson. Ethan stated: “I observed evidence of student learning as students could be heard discussing their findings.” Ruby, a high school fellow from cohort 2, shared the following feedback with Piper, after observing her lesson:

> It is obvious that with teachers like you, students in elementary school are learning a lot. Using various modalities, as you did, showed that when given
various ways to learn, students are successful in learning and remembering as attested to by the fact that they remembered the experience days later. (Ruby, High School Teacher, Cohort 2)

In another cohort 1 debrief, Holly, a middle school fellow, praised Lorraine, an elementary fellow, for the way she used increased engagement of her students through a game to support vocabulary acquisition. In the debrief Holly stated: “You increased your student’s engagement which helped their vocabulary acquisition because it showed the terms in context and visual interactions with game.”

There were also several examples of fellows personally reflecting on ways that they could change their own practice or incorporate something new to better support student success in their own classrooms. For example, in his written personal reflections following a debrief on his lesson, Caleb, an elementary fellow from cohort 1 writes: “I now know how to look at misconceptions in terms of supporting student success.” In this example, Caleb demonstrates how participating in a V-PLC debrief which involved a discussion about student misconceptions helped him to develop an understanding of how to use misconceptions to support his student success.

Other participants also found tangible value in observing other fellow’s teaching methods and classroom practices. One example of this can be seen with, Zoe, who wrote the following in her personal reflections after debriefing her V-PLC peer and elementary fellow, Lorraine:

When I observed Lorraine’s lesson, I saw that explicitly asking students to interact and use text to formulate responses is key to ensuring their individual success. As a result of the debrief I learned that a strong focus on reading can strengthen students’ science content knowledge. (Zoe, Elementary Teacher, Cohort 1)
In other cases, participants identified things that had stood out to them during a V-PLC debrief meeting. They deemed these important for supporting students’ success and reflected on this in their personal reflections. A good illustration of this is Lily, an elementary fellow from cohort 2, who on completing the V-PLC debrief for her lesson, wrote the following personal reflection: “Choices proved to lead to more engagement and thus more student success.”

In other examples found in the data, fellows were not as explicit in identifying student success, but still demonstrated that the experience of being a member of a V-PLC and undergoing multiple debriefs permitted fellows to develop understandings of the importance of creating learning environments that were focused on student success. For example, Leona, an elementary fellow in cohort 2 was given the following feedback on her lesson by Isabella, a middle school fellow: “Even though you teach very young students, I like how you don’t compromise accuracy.” Here, a middle school peer identifies and praises an important aspect of Leona’s practice that she views as important for the success of the students in that classroom. In another example, Greg, a high school fellow in cohort 2, provided the following feedback to Gabriella, an elementary fellow: “It was great to see students working together to solve problems.” Once again, this demonstrates an important piece of praise for good teaching practice, which has been provided by a peer who teaches at a higher level (high school) in the school system. Feedback like this, is confirmatory of good practice but also personally encouraging for elementary teachers who freely admitted to being intimidated by their upper level peers before they begin the V-PLC phase.
The impact of debriefing in a community of peers from the three levels in the school system also included the benefit of observing teaching from outside of a fellow’s comfort zone or wheel house. In one cohort 3 debrief, Julia, an elementary fellow, shared with Sophia, a high school fellow, how observing her lesson had impacted her awareness of her own practice. In the debrief, Julia states: “When I think about your lesson in terms of student success, I realize how important it is for me to shift the accountability of learning to the students.” Julia identifies and reflects that observing a high school science lesson has allowed her to see the importance of certain practices that she needs to focus on in her teaching. This shows an important upshot of V-PLCs.

The data shows that elementary fellows identified, discussed, and received feedback about student success during the five V-PLC debriefs they experienced during this phase of the program. Across the three cohorts of fellows, there were a total of 60 V-PLC debrief meetings and different kinds of student success were referenced during many of these debrief meetings. These references included, evidence of student learning during student-student discussions, using various modalities to allow students to choose how they engage with material, and using different techniques to increase student engagement. Many fellows also reflected on their own practice and how they could incorporate things they had seen, learned, and come to understand during the observation/debrief process with peers from middle and high school. In addition, the data shows that fellows are aware of what promotes student success despite not always explicitly referencing the notion of student success. Fellows from elementary, middle, and high school settings praised one another and reflected on ways to better support student success in their own practice.
Theme 2: Student Understanding

Student understanding was a focus in several V-PLC debrief discussions and fellow reflections. Data occurrences for student understanding totaled 49 and fell into two broad groupings. The first grouping was fellow observations of ways to check for and/or enhance student understanding during teaching. The second grouping involved fellow reflections around how they wanted to incorporate using student understanding in their practice or how student work could be useful in identifying the level of student understanding.

First, the fellows identified many ways that student understanding can be enhanced during teaching. Some examples of these observations included verbal feedback made by Marcia, a cohort 1 elementary fellow, during a debrief of Zoe, also an elementary fellow. Marcia stated to Zoe: “I noticed how you used a simple reading strategy to enhance a content area lesson and student comprehension.” Similarly, during a cohort 2 debrief, Eva, a middle school fellow, commented to Gabriella, an elementary fellow, how she appreciated the value of allowing students to ‘mess around’ with the materials in the lesson. Eva states: “I found it very helpful to see how messing about can feel challenging, but ultimately leads to better understanding in the long run.” Here again, there is evidence of the benefit associated with having vertically aligned peers providing feedback to their V-PLC peers.

In another cohort 1 debrief, a wonderful piece of feedback occurred between Mia, a middle school fellow, and Daniel, a high school fellow. I included this exchange in the findings because there were two elementary fellows also in this V-PLC and present at the debrief. Although they did not make this statement or directly receive this feedback, they
were integral to the community context in which the feedback was given, and this is an example of one of the benefits of participation in a V-PLC. The feedback Mia gave Daniel about the interactions between his high school chemistry students was as follows:

Throughout their academic exchange and quest to explain, they used such fabulous language, in turn they demonstrated a deep understanding of force, pressure, stability and collision of particles. (Mia, Middle School Teacher, Cohort 1)

Some other debrief examples included fellows supporting good practice around student understanding, such as Ella, a cohort 3 elementary fellow, who commented on Abigail, also an elementary fellow: “I am glad to see that you checked for understanding, guided them along the way, repeated and reinforced.” And Gabriella, an elementary fellow in cohort 2, who provided the following constructive feedback to Alfred, a middle school fellow: “Refer back to the specific language you want students to use when trying to explain their understanding.”

The second grouping of findings involves fellows reflecting on ways they want to incorporate student understanding into their practice, or, as in these first examples, use student work to identify the level of understanding students had following a lesson. In this first example, Peyton, a cohort 1 elementary fellow, expressed how useful it was to use student work to assess understanding during the debriefing of her middle school peer, Mia. Peyton stated: “When we looked at students’ work we gained more insight in student understanding of the lesson.” Similarly, Grace, a cohort 1 elementary fellow, identified why she felt it was useful to look at student work during the debrief of Lorraine. Grace stated: “Looking at the student work we were able to highlight student understanding and see the language development in 2nd grade.”
Examples in the data of fellows identifying practices they wanted to incorporate into their own teaching included Chloe, a middle school fellow from cohort 1, who after watching Peyton, an elementary fellow, stated:

I would like to, as Peyton did—more regularly allow time for students to re-think their answers at the end of a lesson and allow the opportunity to modify their answer at the conclusion of the lesson. (Chloe, Middle School Teacher, Cohort 1)

In another example, after a cohort 2 debrief meeting, Lily, an elementary fellow, reflected that she: “Got some great ideas on how I could check in with my students to check on their understanding.”

The elementary fellows discussed and identified ways to check for or enhance student understanding during teaching. Additionally, elementary fellows reflected on how they wanted to incorporate using student understanding in their practice or how using student work could be useful in identifying the current level of student understanding.

**Theme 3: Thinking, Reasoning and Questioning in the Science Classroom**

Another important theme seen in the data analysis included two sub-themes. These sub-themes are fellow references to developing student thinking and reasoning, as well as the use of questions to stimulate the development of student thinking and understanding. These two sub-themes are closely related but differentiated enough to justify separate sub-theme categories.

**Developing student thinking and reasoning processes.** From V-PLC discussions and reflections the elementary fellows found significance in developing and
better understanding student thinking and reasoning processes in science. There were 54 coded examples of this in the data. One example of this was seen in the way Caleb, an elementary fellow, chose to ask his students what they thought was happening at the beginning of his lesson on the states of matter. At the beginning of his lesson, Caleb simply asked his students, “What is your idea?” In the V-PLC debrief of his lesson, Caleb’s peers identified that they felt this was a really nice way to coax students into talking about what they were seeing. However, the best explanation for this introductory question comes from Caleb himself. When describing why he used this approach at the beginning of a lesson, Caleb stated: “It allows them to think freely with minimal risk.”

Allowing students, the opportunity to think was a common way that fellows described their peers’ practice or explained why they conducted a part of lesson in a certain manner. One such example comes from an interaction between Sarah and Daniel, both high school fellows. Again, this interaction is important because it was witnessed by two elementary fellows also present in the V-PLC debrief. Sarah states: “During your lesson, I saw first-hand the significance of allowing student to struggle through the thinking process.” In another cohort 1 V-PLC debrief, Lorraine, an elementary fellow, provided the following feedback to Linda a high school fellow:

Watching your lesson, I learned how inquiry can be introduced to students in a guided fashion so that they can get comfortable with thinking critically and using their prior knowledge to solve science problems. I could see how the students thought through the science work and what they mastered and could still develop. (Lorraine, Elementary Teacher, Cohort 1)

Other examples of fellows examining student thinking as an indicator of student success were found in the data. For example, Peyton, an elementary fellow in cohort 1, wrote in her post-reflections: “Students had an opportunity to re-think and change their
sorting at the end of the lesson. This is good scientific practice.” In another cohort 1
debrief, Nancy, a high school fellow, provided the following constructive feedback to
Grace, an elementary fellow, in which she suggests allowing students a little more time to
think and process the information they are grappling with. Nancy stated: “Students often
need to pause and process information.”

In the data, discussion as a means to further student thinking was also identified
as a significant method for supporting and developing student thinking. In a cohort 1
debrief, Kathy, an elementary fellow, shared the following positive feedback with Zoe,
also an elementary fellow:

The idea of coming to consensus created a need for students to be able to
support their science thinking in discussion. You helped to facilitate the group
discussion by posing questions, especially to the groups that were undecided.
Even when students disagreed with each other. (Kathy, Elementary Teacher,
Cohort 1)

Another cohort 1 V-PLC debrief also referenced discussion as a way to support
student understanding. In this example, Ethan, an elementary fellow, expressed to Sarah,
a high school fellow, that it was clear to see that the students were developing their
understanding through the student-student discussions that could be heard on the video of
the lesson. Ethan stated: “Students developing their understanding of the material was
evident as the students could be heard discussing findings.” In this example, Ethan was
referencing the high school biology lesson he had observed via video. In this video, it
had stood out to him that the students were taking their time to discuss their findings from
their lab and developing their understandings of the concepts through these discussions.

In the data, another area fellows identified as important for developing student
thinking and reasoning was the use of evidence to support thinking. For example,
Peyton, an elementary fellow, stated to Mia, a middle school fellow: “I see how you allowed your students to explore their misconceptions by being challenged to support their thinking with evidence.” In another debrief, Peyton also praised Daniel, a high school fellow, for the way he was able to encourage his students to use evidence to support their thinking. Peyton stated: “I saw evidence of your students’ learning because there was lots of student-student discussion and you encouraged them to use evidence to explain their thinking.” Here an elementary fellow is benefiting from seeing student-student discussion in a high school chemistry class and developing her understanding of how a teacher encourages students to use evidence in support of their thinking. She also experiences and reflects on how this is important for developing student understanding.

Another aspect of student thinking that fellows identified as important was the active engagement of the teacher in pushing students to further their thinking. One example of this occurred in a cohort 2 debrief, where Faith, an elementary fellow, praised James, a high school fellow, for his active efforts to further the thinking of his students. Faith stated: “I love that you walked around to further the students thinking.” There was also an example of this in a cohort 3 debrief where Riley, a middle school fellow, shared with Julia, an elementary fellow, how much she appreciated the active role that Julia was taking in getting students to further and reinforce their thinking. Riley stated: “You floated around the room, group to group. You did not answer their questions directly but reinforced their thinking by encouraging them to continue asking questions to discover for themselves.” This statement is an example of how elementary fellows both identified excellent practices in middle and high school science classrooms and received praise from middle and high school peers for using excellent practices in their elementary
classrooms. This is a fitting lead into the next sub-category, as one observes the connection fellows made between advancing student success by focusing on student thinking and using questioning as a tool to support this development in their students.

**Questioning to develop student thinking and understanding.** There were many examples of fellows identifying, discussing, and reflecting on the effective use of questioning to support the development of student thinking and understanding. For example, in one cohort 1 V-PLC debrief Peyton and Caleb, both elementary fellows, were particularly impressed with the lesson they observed that was taught by one of the high school fellows, Daniel. Peyton shared the following positive feedback with Daniel: “When your students are discussing, and you listen in, you are asking questions that probe into student thinking and require them to think deeply or explain further.” Caleb, also picked up on the use of questions by Daniel, stating: “You kept kids on task with questions that had them focus on what was essential to understanding and making sense of what they saw.” However, Caleb also had some constructive feedback for Daniel, stating: “At times students seemed on track and the questions seemed to derail them or take them away from their line of thinking. Perhaps you can give them more time to think.”

After participating in a cohort 3 V-PLC debrief meeting, an elementary fellow, Mackenzie, reflected on what she had taken from the process of observing and debriefing Jocelyn, a high school fellow. In her reflection Mackenzie writes: “After this debrief I realize that students must be engaged and be a part of their learning. Asking questions is a way of doing this and having them think.” Mackenzie then continues further with her reflection writing:
I was impressed how Jocelyn made it clear that she wanted her students to take ownership for their thinking. She wanted them to ask questions, work collaboratively, and “struggle” (a bit) to work through her lab. Through her guidance students were able to have those “I got it” moments, myself included. (Mackenzie, Elementary Teacher, Cohort 3)

Fellows also noted how important questions were for promoting deeper understanding in their students. For example, Kathy, a cohort 1 elementary fellow, praised Leah, a high school fellow, for her use of questions to prompt students to think deeper about a concept or observation. In her feedback to Leah, Kathy stated:

You did a great job as a guide from the side with your inquiry activity. You asked questions like “can you mention anything else about the area based on your knowledge?” and “what other evidence do you have?” and I liked the way you used those questions to plant a seed with the students and then move on and have it take root. So that they did the work and heavy lifting. (Kathy, Elementary Teacher, Cohort 1)

In another cohort 1 V-PLC, Peyton, an elementary fellow, also provided positive feedback to Caleb on how he used questions to have students think deeper. Peyton stated: “It was great to listen to how Caleb questioned student observations as a means of promoting deeper understanding.”

Fellows identified and praised their peers for their use of questions on many other occasions. Such examples included Ethan, an elementary fellow from cohort 1, praising his peer, and elementary fellow, Zoe’s efforts to use questions to show student learning and incorporating the use of text to provide evidence to support their answers. Ethan stated: “The answers students gave during teacher questioning were great. And they were consistently reminded to go back and use the text to support their answers.” In a separate V-PLC debrief, Zoe, also provided praise for the use of questions in the lesson she observed, that was taught by Sarah, a high school fellow. In her feedback, Zoe stated:
I saw evidence of student learning in your lesson, when your students were having ooh and ah moments based on the types of questions asked by students and answers given by students when asked. (Zoe, Elementary Teacher, Cohort 1)

In a cohort 3 V-PLC debrief, elementary fellow, Julia also identified and praised the effective use of questions by her high school peer, Sophia. In her feedback Julia states: “I loved that when students ask you questions you reply with thought provoking questions.” Some fellows were simply amazed at the level of questioning that was employed at the elementary level. For example, James, a high school fellow, had the following to say to Stella, an elementary fellow, after observing her lesson: “It is quite eye opening to see the level of kindergarten and more than this, the level of questioning you use with your students.” Other elementary fellows in this same V-PLC debrief also found Stella’s use of questioning to be exceptional. For example, Gabriella reflected to Stella: “Your questioning was great” and Faith praised Stella, stating: “I like that you used lots of clarifying questions with your students.”

In a later debrief within the same V-PLC, James again had high praise for his elementary peers. In his feedback to Gabriella, James states: “Yours kids worked well together to problem solve and it was great that you get them to answer in-depth questions on why they did what they did.”

The data also showed some examples of fellows providing constructive feedback about how to better incorporate the use of questions into their lessons. For example, Riley, a cohort 3 middle school fellow, asked Julia, an elementary fellow, to consider whether the student actually know enough about questions to create a ‘good’ question. Riley stated: “Do the students really know how to ask a good question or, what a good question is?” After receiving feedback from her V-PLC, including the feedback from
Riley, Julia wrote the following in her post-debrief reflections, which shows that she took the feedback onboard and was wrestling with how to incorporate this into her teaching. Julia wrote “I need to think about student’s background knowledge about questioning. Which means I also need to teach what is a good question to some students.”

In another cohort 3 V-PLC, Zola, a high school fellow, also provided constructive feedback to an elementary fellow, Ella, about her use of questions. Zola stated:

> It seems that the students were having a hard time developing questions, or that they were not used to it. Perhaps provide guiding questions initially to support the students learning how to use or develop questions. (Zola, High School Teacher, Cohort 3)

After receiving this feedback Ella writes in her post-debrief reflection: “I should consider using different starter questions to better support struggling students.”

Throughout the data other elementary fellows also demonstrated they were considering their use of questions. For example, after her lesson debrief, Faith, an elementary fellow wrote the following in her post-debrief reflection: “I gave a good amount of time for students to talk about what worked or changed. But, there were not enough questions or comments about what they were learning in the lesson.” Ella, an elementary fellow from cohort 3, wrote in her post-debrief reflection:

> I can see how the demands of the curriculum increase with the age and grade. I can also now see how much I need to let students develop questions on their own instead of always giving answers or questions to them. (Ella, Elementary Fellow, Cohort 3)

In her post-debrief reflection, Julia, also an elementary fellow in cohort 3, pondered how she can incorporate and develop the skill of questioning into her practice. She wrote: “How can I develop my practice of questioning?” Cecilia, from cohort 3, wrote in her post-reflection debrief: “After this debrief I am better able to think about
ways to better facilitate independent and guided reading of non-fiction text and generating questions suitable for a primary grade level.”

**Student learning and success from teacher V-PLC learning.** Finally, although my data analysis produced several well supported themes, these are purely based on my own interpretations and conclusions drawn from my interaction with the data as a researcher. In light of this, I was interested to know about how the elementary fellows themselves saw the impact of the V-PLC on their students’ success. One of the questions on the post fellowship survey addressed this explicitly and written responses of fellows shed some light on how they saw the impact of the V-PLCs on their own students.

Several fellows felt that their students benefited from more consistent science instruction and the incorporation of different tools in the classroom. Peyton, an elementary fellow, from cohort 1 wrote, “My students were receiving more consistent science instruction. They were also impacted because my experience has allowed me to be a more informed teacher.” Whereas, another fellow stated:

> I think this experience has impacted my students in a positive way. I am able to take back warm and cool feedback from year one to my classroom, as well as different teaching tools that I have learned from my colleagues in year two. (Abigail, Elementary Teacher, Cohort 3)

The positive impact of being in a V-PLC with upper level peers was mentioned as being important by Cortney, a cohort 2 fellow:

> One way this experience impacted my students was implementing new styles of teaching. Seeing middle school students walking around answering questions gave me the flexibility to try it with my own class. In addition, learning about different Internet websites and resources were helpful as well. (Cortney, Elementary Teacher, Cohort 2)

Zoe stated: “I've filmed many more lessons since being involved in the V-PLC. Since I am a K-5 science facilitator, I often think about how concepts grow across and deepen,
but now I think even beyond the elementary years.” Ella stated: “I think it was positive all the ideas that we talked about as a group, I tried out on them and using the ideas of the authentic literature and having the students relate to that before they built their bridge I think benefited them in a great way.”

Faith stated: “It helped me validate what I was sharing with them. Also, it helped me communicate with my families and share with them the importance of Science (colleagues too).” Robin stated: “I could tell them that I knew they learned a topic previously and to recall it, or to know that they would need this concept in years to come.”

**Discussion and Implications**

In their chapter, Rigor and Equity by Design: Locating a Set of Core Teaching Practices for the Science Education Community, Windschitl and Calabrese Barton (2016) present a new vision of what high quality science teaching and learning should incorporate. Part of the vision they lay out focuses on developing a professional support system for teachers to develop what Bryk (2009) describes as a shared language and conception of goals and learning for students supported by common evidence of what constitutes student learning. In their experience of the V-PLC model, the 28 elementary science fellows participated as members of a social community that provided an opportunity for them to share and build knowledge with other K-12 science teachers, specifically focused around supporting student success in the science classroom. During their participation, elementary fellows discussed, observed, and reflected on the shared
language of science teaching and how they and their peers understood and supported student learning in their practice. They used evidence to ground their discussions and developed shared understandings of the ways that good science teachers at all levels of the K-12 spectrum provide effective support to students in the learning of science. The elementary fellows gained new knowledge about supporting student success and also shared their own knowledge of how to support student learning and thinking in science.

The major areas that fellows focused on were: Identifying student success, developing and identifying student understanding, and supporting student thinking, reasoning, and use of questioning in the science classroom. Each of these is discussed briefly below.

Identifying Student Success

The elementary fellows in V-PLCs were highly engaged in working to identify ways to best support their students’ success. This is a positive finding, in contrast to the larger picture of elementary science teaching in United States as reported by Roth (2014), who presents a very somber overview of elementary science. Although there may be “hands on” activities, there is seldom any connection made to scientific concepts or practices (Abrahams & Reiss, 2012; Ogborn et al., 1996). Often the best hope is that the elementary science teachers will at least attempt to make science engaging and interesting for their students (Roth, 2014).

It is exciting to see that elementary fellows in the V-PLCs recognized that identifying the level of student understanding was important to them. Additionally, they distinguished that good science teaching incorporates student understanding and that students need to be challenged. This is a really important and positive result from the V-PLC model, as the literature identifies that many science lessons taught at the elementary
level fail to address student understanding (Banilower, Boyd, Pasley, & Weiss, 2006; Scher & O'Reilly, 2009; Weiss et al., 2003). The failure to support student understanding in the elementary science classroom occurs both in terms of presenting material at a level appropriate for current student understanding and in supporting the development of student understanding in new scientific concepts (Furtak & Alonzo, 2010; Patrick & Mantzicopoulos, 2015; Roth, 2014).

Part of the use of questioning in the science classroom can be closely linked to supporting student understanding. But other aspects of using questions incorporate developing critical thinking skills and using evidence to reason. To see evidence in the data that elementary fellows are actively incorporating these skills into their practice and they used the V-PLC as a source of developing knowledge to learn and develop new ways to use questions with their student is a promising finding. The literature indicates that the majority of elementary science lessons do not utilize questions that further student understanding (Gillies, Nichols, Burgh, & Haynes, 2014; Newton, Driver, & Osborne, 1999; Reinsvold & Cochran, 2012) or do not allow enough time for sense making through (Roth & Garnier, 2007).

The literature contains plenty of evidence to suggest that many elementary teachers hold pre-existing beliefs about what their students cannot do which often negatively impacts what they do in their teaching (Brophy, 1979; Brophy & Good, 1970; Good & Lavigne, 2017). Yet the findings from this study show that the elementary fellows saw their role as critical for their students’ success in science. It shows their self-efficacy for science teaching and how self-efficacy can be learned among elementary teachers to promote science (Gunning & Mensah, 2011). This is another positive finding.
and suggests that, contrary to the notion of seeing their students as not being able to do or learn science, they see their students as being capable of high achievement in science and that as their teacher they can develop practices to promote student learning in science.

**Conclusions**

The elementary fellows engaged in the V-PLC model show evidence of having created knowledge of practice as described by Cochran-Smith and Lytle (1999) from interacting in their PLCs about supporting student success in the science classroom. Indeed, they also seem to have provided some useful knowledge on how to support student success in science from their upper grade level peers. As one considers high-impact science teaching practices to align with a new vision of high quality science teaching and learning as called for by Windschitl and Calabrese Barton (2016), one might consider that the elementary fellows socially constructed a supporting practice focused on understanding how to best monitor and support student success in science. Windschitl, Thompson, Braaten, and Stroupe (2012) described a series of ‘core tools’ that they developed for pre-service science teachers in which they envisioned provided the tool in a top down type strategy. In reality they report that their core tool became a socially constructed tool over time as their subjects discussed and developed ways to utilize this based on their social interactions and individual context.

In light of this, they re-named the tools as “Priming Tools” (p. 192). In the V-PLC model, fellows are not provided tools to focus their practice or debriefs; however, in the data, it is clear that much of their discussion focused on supporting student success in the
science. In the V-PLC model, the fellows, through social construction, have established the importance of sharing knowledge about identifying and supporting student success within their K-12 vertical learning community and have endeavored to socially create and share knowledge about methods to best facilitate student success in the science classroom. I posit that a critical component for long term K-12 student success in science, as called for by the NGSS, must be the sharing of knowledge of practice amongst elementary, middle and high school teachers to facilitate elementary science teachers in identifying and supporting student success in science at the elementary school level. With this in mind, ensuring student success in these years is critical to the continuum of science learning, even at the post-secondary level. Therefore, a teaching practice for identifying and supporting student success at the elementary level should be established. In this study, one model that supports this type of practice development for current practicing elementary teachers of science is the V-PLC model.
Chapter V

FINDINGS

VERTICALLY ALIGNED PROFESSIONAL LEARNING COMMUNITIES FOR ELEMENTARY SCIENCE TEACHERS’ PROFESSIONAL DEVELOPMENT

Abstract

This qualitative exploratory case study, examines elementary science teacher experiences in vertically-aligned professional learning communities (V-PLC). The goal of the study was to develop an understanding of what science teaching practices elementary science teachers chose to focus on when engaged in a V-PLC. Additionally, the study aimed to examine if or how these practices were reflected in or supported core science teaching practices. The study presents findings that contrast the literature, suggesting that elementary school teachers are actually well prepared to implement certain practices that are supportive of core science teaching practices. In particular, elementary teacher preparation and knowledge of literacy skills enabled elementary teachers to socially construct knowledge which facilitated middle and high school teacher development, improvement and understanding of these skills. Elementary teachers also socially constructed knowledge about ways to ensure rigor in student learning through observation of their peer’s teaching, discussion, and reflections. The findings of the study also support other research findings that indicate a focus on improving aspects of the
lesson, rather than actions of the individual creates a more constructive and student result focused community.

**Introduction and Literature Review**

Confounding the science deficit in elementary classrooms is the adoption of the Next Generations Science Standards (NGSS), or standards based on the NGSS, in an increasing number of states. The major issue with the adoption of these new standards is that they are based on a vision of science education that envisions a science teaching as a K-12 progression of knowledge which progressively builds each year to ultimately create a student who can think, reason and problem solve using both scientific and engineering-based ways of knowing and logic. Of course, this requires that during the first seven years of a child’s school career they receive excellent science education that is grounded in a solid understanding of the new vision for science learning in K-12 school.

**High Leverage Teaching Practices in Science**

There is an emergent trend in teacher education research to focus on identifying high impact teaching practices that support student success (Lampert, 2010; McDonald, Kazemi, & Kavanagh, 2013). As Zeichner (2012) points out, this notion is not new, indeed historically there were serious efforts to focus on identifying teaching practices that supported student success and designing teacher preparation programs around teaching these practices. In the first half of the 20th century, several researchers
established very impressive projects that employed a variety of methods and attempted to scientifically pinpoint what good teaching practices were. These early research projects included work such as the Commonwealth Teacher Training Study, published by Charters and Waples (1929) at the University of Chicago and the Measurement of Teaching Ability by Barr (1935), at the University of Wisconsin. Later in the 20th Century other researchers such as Brophy (1979); Clark et al., (1979), and Shavelson and Stern (1981) attempted to study teacher practices from the psychological perspective of behaviorism. Later work in the 1990s was grounded in much of the behaviorist work with the addition of a cognitive aspect (Sykes & Burian-Fitzgerald, 2004; Zeichner, 2006, 2012). Science teacher standards such as the National Science Education Standards (National Research Council, 1996) laid out practices that teachers should know and be able to do and were grounded in the same aforementioned behavioral and cognitive theory.

Recent publications have identified “core” teaching practices. These are also sometimes known as high-leverage teaching practices (Loewenberg Ball & Forzani, 2009; McDonald, Kazemi, & Kavanagh, 2013; Windschitl et al., 2012). Loewenberg Ball and Forzani (2009) define high leverage practices as:

Teaching practices in which the proficient enactment by a teacher is likely to lead to comparatively large advances in student learning. High leverage practices are those that, when done well, give teachers a lot of capability in their work. (pp. 460-461)

In science education, practices specific to science teaching were first explicitly identified by Windschitl et al., (2012). The authors named the practices, high leverage practices (HLPs). HLPs for science teachers include one planning practice, and three practices centered on discourse, namely eliciting student ideas, supporting students in
sense making and encouraging students to use evidence-based explanations (Windschitl et al., 2012).

Focusing on teaching practices has been shown to have the biggest impact on student success, as opposed to context, evaluation or goal setting (Rockoff, 2004; Seidel & Shavelson, 2007). Unfortunately, the current accountability focus is one grounded in policies that assess teachers and school leaders using student performance data and value-added measures (Harris, Ingle, & Rutledge, 2014).

There have been, however, some attempts to integrate practices into teacher professional development. In a study that examined learning progressions and formative assessment, Furtak (2012) suggested that in the future, useful professional development should be focused upon relevant core instructional practices.

The shift back towards practices in teacher education research has also been acknowledged within the science education community, with Windschitl and Calabrese Barton (2016), issuing a rallying call for science education researchers to work together with classroom practitioners to develop a clearly articulated vision for instructional excellence that is defined by student engagement in science and core science teaching practices.

**Elementary School Science**

In a national survey taken by Banilower et al., (2013), only 25% of elementary teachers surveyed felt that they were very well prepared to encourage students’ interest in science, only 28% felt that that were well prepared to anticipate student difficulties of misconceptions with certain content areas within science, and only 15% felt that they
were very well prepared to support English language learners in learning science. These figures are troubling because today more than ever before, a superior science education experience for students in elementary school is critical for future success in their schooling career.

One of the issues, that plagues elementary science is that elementary teachers have traditionally been prepared as generalist educators (Kier and Lee, 2017) with very little focus, if any, on science teaching during their pre-service teacher coursework (Appleton & Kindt, 1999). Many elementary teachers also have an inadequate academic background for teaching science (Lee et al., 2008; Tilgner, 1990; Tosun, 2000). It is hardly a surprise then, that amongst practicing elementary teachers, there is a lack of desire to teach science at the elementary level (Abell & Roth, 1992; Appleton, 2013; Avraamidou, 2013; Gunning & Mensah, 2011).

The concerns around science education at the elementary level are not wholly based on the inadequate background and preparation of elementary teachers. It has been well documented in the literature that district and government policies focused on accountability in English and mathematics have had a pointedly detrimental effect on science in elementary school (Buczynski & Hansen, 2010; Blank, 2012; Mensah, 2010). Ill-considered policies, a failure to adequately address elementary science teacher preparation, and a lack of effective professional development for practicing elementary science teachers has resulted in the gloomy state of elementary science in the United States which Olson, Tippett, Milford, Ohana, and Clough (2015) call a national concern.
Professional Development

The literature on professional development (PD) clearly identifies what teachers need in order to be successful. Effective professional development (PD) must be deeply embedded in the content (Banilower, Heck, & Weiss, 2007; Cohen, 1990; Garet et al., 2001), designed to involve active learning (Banilower et al., 2007; Mundry & Loucks-Horsley, 1999), able to connect teachers’ to their own practice (Fullan, 2007; Loucks-Horsley & Matsumoto, 1999), and part of a coherent system of support (Reiser, 2013). Additionally, effective PD must occur over a sustained period of time (Crawford et al., 2014; Sandholtz & Ringstaff, 2016)

Unfortunately, the kinds of PD offered to teachers varies extensively, in what Wilson (2013) described as, “a carnival of options” (p. 310). Reiser (2013) suggests that professional development for science teachers need to be far more consistent and address areas in meaningful and focused ways. My study occurs in the larger context of a two-year program, designed to provided sustained, supportive PD for K-12 science teachers, through a variety of structures, systems and networks.

Professional Learning Communities

Learning communities are commonly defined as groups of people that work together on an ongoing basis to share and create knowledge of a common interest through the sharing of individual resources and by engaging in critical dialogue (Wenger, McDermott, & Snyder, 2002). A commonly used definition for professional learning communities (PLCs), identifies five aspects critical for PLCs. The five dimensions are 1)
supportive, shared leadership, 2) collaborative learning with a student needs focus, 3) shared vision and values focused on student learning, 4) supportive structural and interpersonal conditions, and 5) shared practice (Hord, 1997; Hord & Sommers, 2008). Although PLCs are deemed as important for encouraging and supporting professional growth amongst teachers, there is a lack of knowledge in the literature about how PLCs are developed and sustained (Dooner, Mandzuk, & Clifton, 2008; Jones, Gardner, Robertson, & Robert, 2013; Tichnor-Wagner, Harrison, & Cohen-Vogel, 2016). This study aims to explore and understand how a vertically-aligned PLC (V-PLC) (which includes teachers from all levels within the K-12 science continuum), might provide elementary science teachers an opportunity to develop and grow in their science teaching practice.

Theoretical Framework

Social Constructivism

This study is grounded in a theoretical framework of social constructivism (Berger & Luckmann, 1966). The philosophy of social constructivism is that individuals develop their own subjective meanings of their experiences as these relate to objects or things (Creswell, 2013). In social constructivism, the process of constructing meaning is individual and embedded within the particular social setting of which an individual is a member (Berger & Luckmann, 1966; Creswell, 2013; Duit & Treagust, 1998). In this study, the elementary fellows are individuals within a larger social setting of a two-year fellowship and more explicitly, within the smaller social context of a V-PLC. During the
period fellows are working in V-PLCs, the knowledge of elementary, middle and high school fellows, is distributed amongst themselves and new knowledge is created socially. Berger and Luckmann (1966) describe the distribution of social knowledge as “an exceedingly complex and esoteric systems of expertise” (p. 46). The scientific knowledge of the K-12 fellows in this study is as Driver, Asoko, Leach, Scott, & Mortimer (1994) explain, symbolic and socially negotiated because in this study participants knowledge was socially shared and generated. The theoretical approach of social constructivism is also a good fit within the field of science itself. Indeed, the authors Millar and Driver (1987) explain that science is understood to be both personally and socially constructed. In conclusion, the theoretical framework of social constructivism fits this study very well.

**Research Questions**

This study examines the following research question: How and why does participation in a V-PLC support practicing elementary science teachers’ knowledge and development of practices that support the discourse based three core high-leverage teaching practices in science?

**Methodology**

This study examines one component of a larger two-year program for K-12 science teachers. Teachers participating in this program are known as science education fellows, however, from this point, I refer to the teacher participants as ‘fellows’.
In the first year of the program, fellows work in professional learning communities [PLCs]. During the first half of year one, the fellows worked in vertically aligned PLCs (V-PLCs) and in the second half of year one, the fellows worked in horizontally aligned PLCs (H-PLCs). During the second year, fellows worked on individual projects known as a growth plan system. This study examines the experiences of the elementary fellows in the V-PLC component of the first year only.

There were 60 fellows who participated in the program. These fellows were selected from five high-needs school districts in the geographical region of the university site. The 60 fellows were split between three grade bands—elementary, middle and high. The 60 fellows were members of three separate cohorts of fellows, with each cohort containing 20 K-12 teachers. Each cohort completed the program during separate years.

During the V-PLC phase each fellow worked in a small group of between four and five fellows. The fellows in this groups represent the three grand bands. Middle and high school V-PLC members were selected by a university leadership team based on the content specialty recorded on their teaching license. The elementary fellows were assigned to the various content areas based on a preference indicated on their application. In each cohort there were usually four V-PLCs, each focused on biology, chemistry, earth science, or physics. In some years these numbers varied due to numbers of fellows in a particular grade band or subject area.

Once assigned to a V-PLC, fellows decided on an area of content that they wished to study as a group. For example, one biology V-PLC focused on photosynthesis. Each V-PLC also mutually agreed upon a research topic that they would all incorporate into
their teaching. Some examples of the research areas that were picked included outdoor education and incorporating technology into the science classroom.

When the content and research focus was decided, the fellows would then take turns to video record themselves teaching a lesson on the previously decided content that also showed their effort to integrate the research focus. This video was then shared on a password protected platform and the other members of the V-PLC were able to observe the video. Once each member of the V-PLC had observed a lesson video, a mutually agreeable time was decided, and a V-PLC debrief was conducted. During this debrief a strict protocol was followed and each fellow completed documentation that recorded their reflections, responses and thoughts of their peers. Each debrief session was also recorded by the V-PLC and this video was shared onto the password protected platform.

As part of the debrief protocol (Appendix A), fellows would provide warm and cool feedback to the fellow whose lesson had been observed on video. Warm feedback is defined as positive encouraging feedback that, for example, identifies an impressive component of the lesson, or demonstrates an action that a peer feels is something they like and want to include in their practice. Cool feedback is defined as constructive criticism, or questions that promote reflection in the fellow who has been observed. Examples of cool feedback could include, observing that some students did not seem to understand a task and asking if the fellow was aware of this, or asking if a fellow has considered using a particular strategy or practice when conducting a particular aspect of a lesson. A general rule for warm and cool feedback is that it should be supportive in nature and provide the observed fellow a series of positives to be proud of with several areas for reflection and future consideration.
The methodology of exploratory case study (Yin, 2013) was used to analyze the experiences of the fellows. Data from written documentation of 60 V-PLC debriefs, personal reflection journals for the 28 elementary teacher fellows and select video data from debrief meetings were analyzed using open and axial coding, to identify emergent themes and unique occurrences during the V-PLC phase of the fellowship. The program as a whole was considered as the bounded case. Fellows were bounded by the context they shared in participating in the two-year program, they experienced the same processes throughout this time. The bounded case is especially significant, because in order to mirror the alignment of science knowledge and skills as called for in the NGSS, a vertical alignment is used to provide a supportive social structure that aims to facilitate the building of knowledge of practice and personal development in science teaching amongst elementary teachers.

Each data source was examined individually, notes made and codes assigned to any observations that were made. The codes and notes from each individual case were then examined and compared across all the other cases. Themes and occurrences were identified, and these findings are reported in the following section.

It is important to point out that there are some data sources from middle and high school fellows that were examined, coded and included in the findings. These data demonstrate the unique value that participation in a V-PLC offers to elementary fellows. These data are included because they either provide context or narrative for the findings or provide interesting or unique evidence that sheds light on the elementary fellow experience.
Findings

In the process of examining the data, I identify four main themes that provide supporting evidence to address my research question. The four themes are as follows: K-12 Scientific Vocabulary; References to Misconceptions; ELA and Science Connection/ References to Literacy; and Using Feedback and/or Assessment to Guide/Impact Lessons. Theme one is the most common code that was identified during analysis of the data for this chapter, with 86 coding incidents. As such, there are substantially more findings and data for theme one than themes two, three and four who have 29, 43, and 16 coding incidents respectively. However, these findings are still important and demonstrate noteworthy ways in which the V-PLC model provides opportunities for elementary fellows to support and develop knowledge of high quality science teaching. Each theme, along with related sub-themes, is described in detail in the sections below.

Theme 1: K-12 Scientific Vocabulary

It became apparent during the data analysis that scientific language was a very common focus for fellows during the V-PLC debrief sessions. There were many significant discussions, positive pieces of feedback, pieces of constructive criticism, and personal reflections around the topic of scientific language, its context, use, and ways in which a teacher could effectively utilize a variety of techniques using scientific language to support and develop student success. In the 60 V-PLC debrief sessions examined,
there were 86 incidents of data that were coded for scientific language. This was the most common code assigned in the V-PLC debriefs for this chapter.

**The vertical nature of scientific language.** Although this study specifically examines elementary teacher fellows, the theme identified was K-12 scientific language because on many occasions elementary fellows either received feedback or provided it to middle and high school fellows about their use of scientific language. Thus, the vertical nature of the V-PLC created the opportunity for elementary fellows to experience and grow in their knowledge and understanding of scientific language in the context of elementary, middle and high school classrooms. Additionally, elementary fellows were able to see the progression of scientific language through the grade levels. For example, Peyton, an elementary school fellow, reflected on seeing common scientific language usage across elementary and middle school classrooms in a V-PLC debrief meeting during which she observed and debriefed a middle school science lesson. Peyton stated the following in her post debrief reflection: “As a result of this meeting, I was able to see common scientific language and procedures across elementary and middle school classrooms.” Another elementary school fellow, Olivia, also reflected on how important it was for her to develop an understanding of the expected growth in scientific vocabulary usage for students as they progress through their K-12 journey. Additionally, she identified that this knowledge was important for her to understand how to better support her students for success in their future school experiences. After her lesson debrief with her V-PLC, Olivia wrote the following reflection:

I found it interesting to hear how the lower grade level science experience is built upon in middle and high school. I am hoping that providing more concrete vocabulary experiences in elementary school will enable students to achieve success. (Olivia, Elementary Teacher, Cohort 1)
This example showed that Olivia was identifying for herself how the sequential progression of knowledge, also known as learning progressions, envisioned by the NGSS, develops through the middle and high school grades. Olivia connected the importance of a good base of science vocabulary for facilitating student success in the upper grade levels. As well as elementary school teachers seeing the progression of scientific vocabulary beyond their grade level, there were many examples of the middle and high school teachers gaining appreciation and respect for the level of scientific vocabulary used at the elementary level. For example, during a V-PLC debrief, Sebastian, a high school physics fellow, expressed to Kathy an elementary fellow, “I was able to gain a better understanding of how difficult scientific vocabulary is, even in the 2nd grade.” During another V-PLC debrief a high school fellow, Ruby, told Lily, an elementary fellow, “I was able to see a 5th grade lesson that showed that students were using high school vocabulary and understanding how to classify living things.” These two examples of high school fellows interacting with elementary fellows during debriefs were important, because it illustrated to elementary fellows the importance of their work with their elementary students for the future success of those students eventually in middle and high school. In this case, it was the use of scientific vocabulary that would support the future success of their students.

Other interactions between high school, middle school, and elementary school fellows were centered around language and best practices for using it effectively. For example, Chloe, a middle school fellow, provided Peyton this piece of constructive feedback during Peyton’s V-PLC debrief: “I feel it would have been helpful if students
had a word bank to use during the activity. Terms such as ‘definite shape’ are difficult for students to come up with on their own.”

In another example, in a V-PLC debrief, Sophia, a high school fellow shared the following with Julia, an elementary fellow: “During this meeting, I have gained a better understanding on what is done at the earlier ages and saw a way to increase student vocabulary.” This is both complementary to Julia and an acknowledgement that watching Julia’s teaching provided Sophia with ideas of how to increase student vocabulary in her own high school setting. Another example of such an interaction occurred between Isabelle, a middle school fellow in cohort 2, and Leona, an elementary fellow. During a V-PLC debrief, Isabelle shared with Leona the following: “Even though you teach a very young age, I like how you don’t compromise accuracy.” Isabelle then provided Leona with solid examples of how she did not compromise accuracy and also added, “the level of vocabulary in 1st grade is impressive!” In one other example, a high school fellow from cohort 2, Eva, shares how Faith, an elementary fellow has provided her with a very useful tool for supporting scientific language success in her classroom. Eva states: “I will give my students a word list in the future when they need it,” after the V-PLC debrief discussed the benefits of a word list for student engagement and success with relevant scientific vocabulary.

Although the vertical nature of scientific language was often discussed between elementary, middle, and high school fellows, there were examples of elementary fellows identifying the development of scientific language usage within the levels of elementary school itself. For example, Grace, a 5th grade elementary fellow commented to Lorraine, a 2nd grade elementary fellow, on the importance of seeing the level of language
development in students currently in 2nd grade. Specifically, she notes how important this is for monitoring student understanding. Grace stated:

I could see how the group looking at student work enhanced student learning by highlighting student understanding and seeing the language development in the 2nd grade students. (Grace, Elementary Teacher, Cohort 1)

Finally, some fellows from the upper grades, such as Daniel, a high school chemistry fellow, simply could not get enough of the V-PLC experience. Daniel shared with Peyton, an elementary fellow how exciting it was to watch her students interact with one another during the lesson and use scientific language to negotiate meaning. Daniel stated:

Some kids were very expressive, with one explaining what a liquid is with motions of his hands, for example, and then banging on the desk to explain what a solid feels like. It was very nice to see how he got his point across. The kids were all trying to figure out the essential characteristics of solids, liquids, and gases. At one point Peyton said something like: “there are no wrong answers…. yet.” Some kids were heard talking about oobleck, and the constant use of language to negotiate meaning was evident. Some students talked about whether something can spread (liquid) or not (solid), but then Peyton poured sand on the table, and asked them if it was a liquid or a solid… (Daniel, High School Teacher, Cohort 1)

Daniel’s excitement for the V-PLC experience was evident throughout all of his debriefs and on many occasions his interactions with elementary teachers were noteworthy for their insight into the practice of science teaching and the high respect which he held for his elementary peers.

In summary, elementary fellows were able to observe the use of scientific vocabulary across the K-12 spectrum and see how elementary science vocabulary is built upon or incorporated into teaching at higher levels. Elementary fellows also received supportive and prescriptive feedback about their use of scientific language in their teaching and how they could improve the emphasis on scientific language. Finally, upper level teachers were extremely impressed with some of the elementary scientific language
they witnessed being used and provided their elementary peers with warm and encouraging feedback.

**Scientific language usage with feedback and recommendations.** There were many examples of fellow interactions during V-PLC debriefs that centered around how to use scientific language effectively with students. One such example, included emphasizing clearly defined scientific vocabulary. For example, Mia, a middle school fellow, stated to Ethan, an elementary fellow: “I liked that you initially reviewed the definition of scientific matter.” This sentiment was also echoed by another member of the same V-PLC during the same debrief by another elementary fellow, Peyton. The positive feedback that Peyton gave to Ethan included: “Use of scientific vocabulary (clearly defined).” Peyton also reflected after this V-PLC debrief and wrote: “During this debrief I observed good teaching practices (strong vocabulary usage and student engagement).”

In another V-PLC debrief meeting, the lack of clear vocabulary definitions was identified during the cool feedback [see methods section above or Appendix B]. Harper and Olivia, both elementary fellows, suggested to Mason, a middle school fellow, that he should really consider using clearly defined vocabulary with his students. They suggested that it would be beneficial at the beginning of a class and through a visual display with a picture somewhere within the classroom. During the cool feedback Harper stated to Mason: “I encourage you to define vocabulary at the beginning of the lesson” and Olivia asked Mason, “have you thought about displaying vocabulary words with a picture?”
In a different debrief that occurred between Faith, an elementary fellow, and Eva, a middle school fellow, like the aforementioned example, suggested that introducing vocabulary early on would be a good way of supporting student success. Faith asked Eva: “Did you think about introducing the vocabulary prior to the lesson?”

Other examples of exchanges focusing on recommendations for teachers to help students be successful with their language use include Peyton, an elementary teacher, who admitted to being surprised at how much her students struggled to use scientific vocabulary to describe similarities between different materials. She noted her colleagues’ advice on vocabulary during her V-PLC debrief and wrote in her post debrief reflection:

I was surprised at how students struggled to verbalize similarities among materials. I would/should have taught more of the characteristics/properties vocabulary prior to this lesson. (Peyton, Elementary Teacher, Cohort 1)

After this debrief Peyton left with a much keener understanding of how important focusing on language was for student success. This improved understanding is seen in a debrief meeting held over a month later by the same V-PLC. During this debrief meeting Peyton described to Daniel, a high school chemistry teacher, how he can better support students to explain their understandings. Peyton stated to Daniel: “Refer back to the specific language you want students to use when trying to explain their understanding” and later in her post V-PLC reflections Peyton wrote, “I will know that I am successful when my students can use topic specific vocabulary fluidly in conversations and writing.”

Fellows also shared knowledge about specific pedagogical tools that could be incorporated into a lesson to help support student success with scientific vocabulary. These tools included an anchor chart and a word bank. Exchanges on these two tools were frequent in the V-PLC debrief sessions. For example, after viewing his lesson,
Abigail, an elementary fellow, asked Max a high school chemistry fellow: “Have you considered using something like an anchor chart with key terms like endothermic and exothermic in the classroom?” Max recorded this suggestion in his reflection notes and subsequently during a later V-PLC debrief he provided Kaylee, another elementary fellow in his V-PLC, with the following positive feedback on her lesson: “I liked the observations notebooks and the anchor vocab with pictures.”

Other examples of fellows recommending the use of such pedagogical tools to one another include Ruby, a high school fellow, who offered the following suggestion to Piper an elementary fellow:

Did you consider using a word bank so students could match the parts of the digestive tract? Is it possible to use some pictures of the animals that you used on the Smartcard and put them on the student’s desks? (Ruby, High School Teacher, Cohort 2)

This suggestion was followed up during the same debrief by Lily, an elementary fellow in the same V-PLC as Ruby and Piper. Lily stated to Piper: “Yeah, I observed you using a lot of scientific vocabulary, for example, esophagus. Perhaps you might consider providing a word bank for your students?”

Other fellows reflected after their V-PLC debriefs about the need to incorporate such tools and structures in their practice. For example, Ella, an elementary fellow, recorded the following reflections:

I must consider using a word bank / giving everyone a list of question words / sentence frames. As a result of this debrief I saw the need and importance of using content vocabulary and the expectation for students to use it/own it. (Ella, Elementary Teacher, Cohort 3)

Positive feedback and encouragement also occurred between elementary fellows who were in the same V-PLC. For example, Leona provided Penelope with the following positive feedback during their V-PLC debrief meeting:

I saw you reminded students that they could use the anchor chart to refresh their memory about the content already discussed and refer back to use the lessons
vocabulary. And good use of scientific vocabulary – absorb, repel, surface tension. (Leona, Elementary Teacher, Cohort 2)

Cool, constructive feedback between elementary fellows was also seen in the data. For example, Stella, an elementary fellow, provided the following feedback to Gabriella, also an elementary fellow, on her lesson: “I would have liked to see them making a chart of the vocabulary they used.”

There were also many examples of feedback on the use of scientific language in the classroom that was both positive and directed at building knowledge of how to support student success in science through the effective use of scientific language. For example, Gabriella, an elementary fellow, wrote in her V-PLC debrief reflection: “Students were engaged, had rich conversations and used rich vocabulary.” Kathy, an elementary fellow, shared the following supportive reflection with Jane, a middle school fellow:

You reminded them to rely on past knowledge, skills, and vocabulary [when] referring them to the WOW wall, reminding them of past experiences with the balance scale and the skill of working from the bottom of the scale, reviewing the differences between qualitative and quantitative data, all the while eliciting the information from the students rather than just telling them. (Kathy, Elementary Teacher, Cohort 1)

Cohort 1 debriefs, in particular, impacted multiple members of that V-PLC. For example, Lorraine, an elementary fellow, reflected after the V-PLC debrief of Grace and stated that: “I could see how the awesome demonstration of content specific vocabulary in written expression helped enhance student learning.” The debrief was on Lorraine’s elementary lesson and many fellows reflected on the impact they felt from watching the lesson and debriefing as a V-PLC on the content. Grace, an elementary fellow, reflected: As a result of this observation: “I plan on putting more emphasis on vocabulary in my classroom.” Holly, a middle school fellow reflected: “I saw how Lorraine increased student engagement and helped science vocabulary acquisition because she showed the terms in context and through visual interactions with a game.” Another member of this V-PLC, Nancy, a high school fellow, wrote the following in her reflection: I saw the importance of emphasis of vocabulary in the classroom, ESOL and students who are
English native speakers still need assistance with science vocabulary.” And finally,

Lorraine reflected on her own V-PLC debrief experience, writing:

Watching back video, I was encouraged by student engagement and accountable talk using content specific vocabulary. My scaffolding of vocabulary and content seemed effective. As always, group feedback was greatly appreciated. (Lorraine, Elementary Teacher, Cohort 1)

Several V-PLC debrief meetings focused more on how scientific language could be used to identify and support student learning. Leah, a high school fellow, reflected that Kathy, an elementary fellow, could identify which students had successfully learned to the use the scientific vocabulary by assessing their homework performance. Leah wrote: “Students needed to use vocabulary appropriately in their homework in order to demonstrate key properties of the volvox.” Volvox is a type of green algae that is often used in classrooms to investigate characteristics or properties associated with evolution.

In another cohort 1 V-PLC debrief meeting, Holly, a middle school fellow, identified how Grace was using writing to assess her student’s understanding of the scientific vocabulary. Holly wrote: “I could see how Grace enhanced student learning by seeing how the students used correct vocabulary in their writing and used correct examples.”

Reading was also identified by fellows as an effective way to support the learning of scientific vocabulary. For example, Zoe, an elementary fellow, identified in her personal reflection on her own V-PLC debrief that “reading was infused into the science class, it reinforced content specific vocabulary.” Additionally, the experiences and real-world connections that fellows brought into their teaching were also appreciated and acknowledged as critical for successful engagement with scientific language. Isabelle, a cohort 2 middle school fellow, wrote the following reflection about her peer and
elementary fellow Leona’s lesson and subsequent V-PLC debrief: “Vocabulary is not compromised but rather complemented with real life experiences.”

The findings showed that elementary fellows received many constructive ideas from their K-12 peers about how to use scientific language more effectively in their teaching. There were also good examples of elementary fellows identifying the need to explicitly identify the expectations for student language use prior to a lesson. Additionally, elementary fellows reflected on ways they identified making the use of scientific language in the elementary classroom more effective. Several tools to support science language acquisition and development were suggested for use in the elementary science classroom. Other findings showed fellows discussing how to support scientific language development, assessment student understanding based on the use of scientific language and using reading to support scientific language development.

**Scientific language, literacy and ELA support.** Another area focused on scientific language that arose frequently during the debrief sessions was how scientific language can be used to support ELA skills and students who are not native English speakers. The diverse student bodies the fellows served impacted the way they planned and used scientific vocabulary.

The use of pictures in combination with scientific vocabulary was identified as a useful literacy tool to improve both written and verbal skills. For example, Sebastian, a high school physics fellow, provided the following constructive feedback to Lorraine, an elementary fellow: “Pictures paired with the correct term would promote both verbal and reading skills. You could use PowerPoint, flashcards and have the students work in pairs.” In the same V-PLC debrief meeting, Holly, a middle school fellow, reflected that
it was really useful to see how important explicit literacy skills need to be incorporated into lessons. Holly stated: “It was helpful for me realizing that science is like its own language and requires specific vocabulary instruction.”

An elementary fellow, Piper, also reflected on the importance of having explicit literacy components in a lesson to support students’ science vocabulary success. In her post debrief notes, Piper wrote: “In future lessons, I would like to explore sentence starters and a science picture wall for improvement of oral/written language.”

Fellows also identified reading as a critical literacy support for improving student scientific vocabulary success. For example, Riley, a middle school fellow, praised Harper, an elementary fellow, for reading and reviewing previously covered vocabulary at the beginning of her lesson. Riley stated: “I liked that the students read the learning targets and reviewed vocabulary previously taught.” In another V-PLC debrief, Riley also provided Julia, an elementary fellow, with praise for her incorporation of literacy strategies in her lesson. Riley stated: “I loved the literacy incorporated into the lesson: sentence starters, clarification of vocabulary, encouragement to use the vocabulary.”

Other fellows were explicit with their focus on the reading aspect of an observed lesson. Elementary fellow, Zoe, provided the following feedback to Maya, a high school fellow:

It was useful to see the importance of using reading vocabulary (cause and effect) as part of a science lesson to help students find connections between language and literacy. Explicitly asking students to interact and use text to formulate responses is key. (Zoe, Elementary Teacher, Cohort 1)

One other important finding was seeing fellows use scientific language as a support for students who were not native English speakers. This was observed in all three cohorts and fellows discussed the benefits in their V-PLCs. An example of this
from cohort 3 can be seen in the positive feedback that Riley, a middle school fellow, shares with Olivia, an elementary school fellow. Riley states:

> There was a clear language and content objective, you repeated the language objective throughout the class, you integrated literacy, used the text for evidence and integrated Spanish and English scientific vocabulary. (Riley, Middle School Teacher, Cohort 3)

After listening to all of the feedback from her peers, Olivia felt happy with how her lesson had gone and had been received by her peers and she stated: “I was especially happy to have a little girl, a newcomer, participate in the lesson by including Spanish vocabulary and definitions.”

In another example of support for non-native English language students, Isabelle, a middle school fellow, identified how important it was for her to see Leona, an elementary fellow, use Spanish to scaffold English scientific vocabulary. Isabelle stated: “It was most helpful to see how you used Spanish to scaffold scientific vocabulary in English.” This feeling of appreciation for using science vocabulary as a literacy tool to support non-native English-speaking students was also present in Chloe’s post V-PLC reflections. Chloe wrote, “The best way to teach language is through science.”

The findings show that elementary fellows received several suggestions from their V-PLC peers to incorporate explicit vocabulary instruction into their lessons. Fellows discussed the use of Spanish to scaffold scientific language support for Spanish speakers and the integration of literacy skills, with scientific language objectives and content goals. Additionally, reading and writing skills for scientific language were discussed and demonstrated. Elementary fellows demonstrated their ability to use literacy skills to support language growth and these practices were acknowledged and appreciated by their upper level peers. Additionally, the elementary fellows learned how to better incorporate
literacy skills to support scientific language development from their elementary and upper level peers. In their use of and discussion about scientific language, elementary fellows demonstrated ability to utilize practices designed to support student sense making. The collaboration and sharing of knowledge with their secondary level peers both reinforced their ability to use these practices and provided them opportunity to see such practices in a different context.

Scientific language for accountable talk, academic conversation, and questioning. In the V-PLC debrief meetings, there are many examples of fellows observing accountable talk and seeing the importance of this in science instruction. Accountable talk, can be described as holding the student responsible for using specific vocabulary in context. It is used both as a measure of accountability for learning (student) and an informal assessment (teacher) of student understanding. One example of this occurred when Mia, a middle school fellow, observed an elementary fellow, Peyton’s, lesson. Mia shared the following positive feedback with Peyton: “I was impressed by the student accountable talk during the activity.” Other fellows in this PLC also commented on how Peyton held students accountable for using scientific language during their verbal responses to questions and it seems that this experience pushed Mia to try and incorporate accountable talk in her own teaching. In a later debrief, Mia asked her V-PLC peers to focus on the “use of accountable academic talk, particularly in group work” as they watched her lesson video.

Other examples of fellows appreciating accountable talk can be seen in the following example from a cohort 2 V-PLC debrief meeting. During the debrief several fellows offer Lily, an elementary fellow, positive feedback about her encouragement of
students to use academic conversation or accountable talk. Ruby, a high school fellow, stated to Lily: “I liked that you had academic conversation/accountable talk during the lesson.” This positive feedback was echoed by Alfred, a middle school fellow. Alfred stated, “Your ‘academic conversation’ reminder was great.” However, Alfred also suggested some ways that Lily could improve the quality of the accountable talk by asking Lily: “Did you consider modelling the ‘accountable talk’ so that students couldn’t use a get out of jail free card and just say ‘I agree with him’.”

Cohort 2 V-PLC debrief meetings also provided other evidence that fellows were focusing on accountable talk in science lessons. For example, Gabriella, an elementary fellow, praised Eva, a middle school fellow, stating: “I like how you held the students accountable for their own definition… Our definition has to work.” In this situation, Eva had taught a lesson in which part of the student activity was to come up with a definition for what they were observing. Although Gabriella was impressed with Eva’s lesson, other comments from the same V-PLC debrief fellows wondered if the students were clear on what a definition needed to include and even how they could go about creating a definition. In her post debrief reflections, Eva, clearly pondered this situation and wrote “Coming up with “definitions” to come up with their own terms – (what is their own terms?) how do I promote their own talk?”

In another Cohort 2 V-PLC debrief Stella, an elementary fellow, received positive feedback from elementary fellows, Gabriella and Faith, on the use of questioning to push students understanding. Faith stated to Stella: “I liked that you provided lots of clarifying questions to students” and Gabriella stated: “Your questioning of students was great.” In a later debrief with the same V-PLC, Gabriella indicates that she was actively thinking
about how to best incorporate scientific vocabulary into her teaching. She writes in her post debrief reflection: “How can I represent the vocabulary used? How can I ensure that dialogue becomes part of learning?”

Cohort 3 fellows also discussed questioning and accountable talk in their V-PLCs. For example, Abigail, an elementary fellow, praised Kaylee also an elementary fellow, for her use of questioning and anchor charts. Abigail stated: “I liked the anchor charts and that you began with a question.” After the debrief with her V-PLC peers, Kaylee wrote in her post-debrief reflection:

It was particularly useful for me to listen to the feedback about making connections using academic vocabulary and hearing how my colleagues use the process of allowing students to come to their own conclusions. (Kaylee, Elementary Teacher, Cohort 3)

The data shows that during the debrief sessions many fellows came to understand the importance of accountable academic talk with respect to scientific language. This focus is one method that supports the central practice of supporting students sense making in science. This understanding occurred through observations of peer’s lessons, receiving feedback from peers during the debrief and the post debrief self-reflection. Elementary fellows were also provided with useful feedback to strengthen their use of accountable or academic talk with students. Additionally, elementary fellows discussed and were provided with ideas for using questioning in their science teaching to hold students accountable for their understanding and conclusions.
Theme 2: References to Misconceptions

Towards the end of the 1980s, researchers began to examine how students see or understand scientific processes or concepts in the world in which they live. Students ideas had been investigated in the previous decade and had been termed ‘misconceptions’ (Helm, 1980), ‘alternative frameworks’ (Driver, 1981) and ‘children’s ideas’ (Gilbert, Osborne, & Fensham, 1982). Vosniadou and Brewer (1992) and Smith, Blakeslee, and Anderson (1993) investigated the phenomena of ‘misconceptions’ from the perspective of conceptual change. Misconceptions can be defined as ideas that provide an incorrect idea about an occurrence, concept, or process and these ideas are based on an individual’s experience (Martin, Sexton, & Gerlovich, 2002).

In the data, there were 29 incidents where fellows discussed the importance of knowing about and anticipating misconceptions in order to better prepare and plan science lessons and support students in their learning. For example, Mia, an elementary school fellow, suggested to Caleb, an elementary fellow, that he might strengthen his lesson if he considered “accurately identifying the misconceptions at the beginning of the lesson by writing it down and revisiting.” During the same debrief, Peyton, an elementary fellow, wrote in her reflection: “I could see how using student work helped enhance my learning by seeing where their true misconceptions are in their written work and communication within groups.”

Using misconceptions as way to demonstrate to students the importance of the use of evidence was also seen in several debrief meetings. For example, Caleb, an elementary fellow, wrote in his post meeting reflections, “It is powerful to use student provided evidence to clarify or debunk misconceptions.” In another cohort 1 debrief
meeting, the following exchange between Mia, an elementary school fellow, and Chloe, a middle school fellow, was observed on video. In the exchange, Mia stated to Chloe: “I could see how you allowed your students to support their thinking with evidence, thus proving misconceptions to student.” In another cohort 1 debrief, Peyton, an elementary fellow, stated to Holly, a middle school fellow: “I could see how you allowed the students to explore their misconceptions by being challenged to support their thinking with evidence.”

In another cohort 1 V-PLC debrief, Kathy, an elementary fellow, identifies how beneficial she feels it is to have watched the lesson of her high school peer, Daniel. Kathy stated to Daniel:

You integrated closed systems into a lesson on gas. The focus of your lesson naturally lends itself to dynamic discussions. I can see their misconceptions being changed simply through their facial expressions. The structure of having students trying to convince each other of their rationale was fantastic. I found it extremely powerful seeing how you had students revisiting their original misconception and validating through the use of their experiences w/demonstrations. (Kathy, Elementary Teacher, Cohort 1)

Grace, an elementary fellow, also comments on the same debrief, stating: “I saw how the students were encouraged to explore their initial misconceptions and then modify their thinking based on demonstration and group discussion.” Grace then continued with her warm feedback and stated: “It is really amazing to see some students that developed or constructed new accurate conceptions based on the activities. They actually moved away from old misconceptions!”

There is also data in the post debrief reflections that shows several elementary fellows noted thoughts about incorporating misconceptions into their own teaching or ways to better accommodate misconceptions in their lessons. For example, Caleb, wrote
the following thoughts after debriefing on his lesson: “My peers helped me to see that by using misconceptions as a guideline I can know what to look for in terms of student success.” He continued and stated: “Possibly I might spend more time to have kids write down their misconceptions so as to better have them confront them when doing the activity.”

Another elementary fellow, Mia, after observing and debriefing Peyton’s lesson, composed the following reflection:

As a result of watching Peyton’s lesson I am going to have a morning message in my classroom that prompts students to think about a misconception to guide class. I think it was very helpful to see a list of misconceptions and think or decide on which ones to focus on. (Mia, Elementary Teacher, Cohort 1)

The data showed that elementary fellows observed and discussed using misconceptions to guide teaching concepts with their higher-level peers. They also demonstrated ways to incorporate misconceptions into their science lessons. Some of their efforts required some adaptations and changes to better incorporate their ideas and in these cases, upper level and elementary peers provided them with appropriate, constructive feedback, to support their growth in their area of practice. Using misconceptions in the ways that the elementary fellows were discussing and enacting incorporates the core practice of eliciting student ideas. One sees that elementary fellows were able to see the power of eliciting student misconceptions through watching their secondary peers. It can also be seen in the data that several elementary fellows after debriefs, actively reflected on how they might incorporate misconceptions into their work more effectively and better understand how to monitor the students understanding based off their explanation of the misconceptions using evidence.
Theme 3: ELA and Science Connections to Literacy and General Language

As well as K-12 scientific language, elementary fellows identified, discussed, received feedback, and reflected on connections between ELA and Science and ways in which literacy and general language development could be supported through science teaching practices. There were 43 incidents of this code identified in the data. In the context of the findings, these data were viewed as differentiated from the theme of K-12 scientific language because the fellows referenced language in general as opposed to scientific language explicitly.

**Using evidence to support a claim.** There are several incidents of debrief meetings examining students’ validating a claim or using evidence to support a claim, a common requirement for students taking upper level elementary ELA tests in the state in which this study is based. For example, Chloe, a middle school fellow, provided the following warm feedback to Mia, an elementary fellow: “I saw that students had to validate their claims, this ties nicely to the ELA state exam and it is an important science practice.” In another debrief Mia, demonstrates that she also recognizes the importance of having students using evidence to support a claim. Mia wrote:

Accountable talk is a priority in group work. Students are given a mystery object with descriptions and are asked to make a claim about what state of matter the object is based on the descriptions. They must use two pieces of evidence to support their claim. (Mia, Elementary Teacher, Cohort 1)

**Literacy and general language in the science classroom.** The data also shows general vocabulary being discussed as a critical component to good science teaching. Chloe, a middle school fellow, writes the following reflection after debriefing elementary fellow Peyton’s lesson in which students categorized matter using properties: “The best
way to teach science is through language.” In contrast to this, Caleb, an elementary fellow, identifies in his constructive feedback to Peyton that he feels there was a need for students to have an improved background in vocabulary to have a deeper experience in the lesson. Caleb wrote: “Kids seem to have needed more experiences with vocab development in order to better describe what they were observing.” Having listened to her peer’s feedback, Peyton identified the following areas she needs to focus on: “I need to explore more ways to incorporate language objectives and vocabulary support in my lessons” and “I will attempt more language specific tasks prior to content.”

In another cohort 1 debrief, Nancy, a high school fellow, reflected that while watching her elementary peer Lorraine’s videotaped lesson, she had noticed that there was a significant emphasis on general vocabulary in the science classroom. She could see how important this was, but also felt that ESOL students needed explicit science vocabulary support. Nancy stated:

I could see the importance of an emphasis on vocabulary in the science classroom. However, ESOL and students who are not English native speakers still need focused science vocabulary assistance. (Nancy, High School Teacher, Cohort 1)

Other fellows reflected on the ways in which vocabulary can be developed. Greg, a high school fellow, reflected after watching Leona’s lesson: “Vocabulary is not compromised but rather complemented with real life experiences.” Whereas, Olivia, an elementary fellow reflected on the warm feedback she received from her peers and wrote: “Positive feedback includes, clear language and content objectives.” Another cohort 3 debrief included similarly aligned praise. Riley, a middle school fellow provided Julia, an elementary fellow, with the following warm feedback: “I like how you have literacy
incorporated into the lesson: Sentences starters, clarification of vocabulary and that you actively encourage your students to use the vocabulary.”

**Reading in the science classroom.** Reading is identified by elementary fellows as a critical tool for literacy and scientific comprehension. Cohort 1 elementary fellow Zoe, stated the following after reflecting on the debrief of elementary fellow, Marcia: “Reading in science can be done and can be interesting. It allows students to make sense of what they are reading.” Another member of the same V-PLC, Sarah, a high school fellow, shared the following with the V-PLC during Marcia’s debrief:

I see the importance of using reading vocabulary (cause and effect) as part of science lesson to help students find connections between language and literacy. Explicitly asking student to interact and use text to formulate responses is key. (Sarah, High School Teacher, Cohort 1)

In a cohort 1 debrief, Maya, a high school fellow, provided the following reflection to her peers after debriefing Zoe, an elementary fellow:

This debrief has made me more aware of what I do in the classroom, but unconsciously. This meeting provided me with other ways of reaching my students to ensure reading comprehension and help them be more successful. (Maya, High School Teacher, Cohort 1)

The data shows that elementary fellows demonstrated an understanding of how important using evidence to support claims is both in science and subjects such as ELA. This is evidence to show that they were engaged in socially constructing, sharing and learning knowledge about the third core practice focused on discourse, encouraging students to use evidence-based explanations. Fellows also demonstrated that they realized this connection to ELA was important for their students overall academic success. Elementary fellows also discussed the importance of general language knowledge and usage for literacy and the building of science knowledge. This was discussed with their
upper-level peers and several techniques for incorporating good vocabulary and literacy strategies were referenced and reflected on. Reading was also identified and discussed as a critical skill for learning science and general literacy support.

**Theme 4: Using Feedback and/or Assessment to Guide/Impact Lessons**

There are many examples of fellows using feedback and/or assessment to guide their practice throughout the data. However, there were 16 incidents in the data of fellows explicitly identifying the use of feedback or assessment to guide or impact a lesson. One such example of this was provided as warm feedback from Sebastian, a high school fellow, to Grace, an elementary fellow. Sebastian stated, “It was great to see you use technology that gave automatic feedback to you, the teacher, so that you could go back and emphasize points that may not have been understood.” Another example that explicitly identified a way a fellow could use feedback to impact a lesson also incorporated technology and was provided by Leona, an elementary fellow, who told Greg, a high school fellow: “I enjoyed how you used the cell phone for your students to be accountable for their work and send a picture of their lab. This created a high level of engagement.” During the same debrief, Isabelle, a middle school fellow, also identified how beneficial it was to see how to use different techniques to assess understanding. Isabelle stated, “As a result of this debrief I got new ideas to assess understanding quickly. I liked the idea of having students send pictures of lab setups as a way to make them accountable for getting work done.”

In another debrief meeting, Ella, an elementary fellow, provided another elementary fellow, Mackenzie, with the following feedback: “Good energy, I saw you
rephrased, restated, redirected and repeated as necessary, I was glad you checked for understanding.” Other fellows were more explicit as they identified how impressed they were with the manner in which their peers used feedback and assessment. For example, Leona, an elementary fellow, stated to Penelope, an elementary fellow, “I notice that you used questioning very effectively to do formative assessments, address misconceptions and to further students understanding.”

Therefore, the elementary fellows demonstrated ways to use assessment to guide or impact a lesson, and they received and provided supportive comments about the use of feedback on their lessons. The elementary teachers then reflected on modes of incorporating quick and effective feedback into their practice.

**Discussion**

In this study, I explored how elementary fellows developed their science teaching practices as they participated in a V-PLC alongside both middle and high school peers. The findings suggest that elementary teachers engaged in dynamic V-PLCs gain significantly in the development of skills, practices and importantly, confidence to continue something they have tried or try to something new.

Several studies have shown that elementary teachers are often not experienced at teaching science that promotes student understanding (Blanchard, Southerland, & Granger, 2009; Lee et al., 2016; Wilson, Taylor, Kowalski, & Carlson, 2010). Yet in the data, there is plenty of evidence which shows that elementary fellows were actively involved in implementing, providing supportive critical feedback about, and learning
about practices related to three of the HLPs [high leverage practices] suggested by (Windschitl et al., 2012). These HLPs were ‘supporting student sense making’, which was evidenced in many of the data described, an example includes, holding students accountable for their use of scientific language, in a practice termed ‘accountable talk’. Two studies found that authentic forms of rigor in classroom talk are more likely to occur when teachers are responsive to students’ ideas (Colley & Windschitl, 2016; Thompson et al., 2016). In this study, the K-12 fellows involved were highly engaged in learning about responding to students needs and polishing their practice to support improved experiences for their students.

Thus, in this study, we can support these findings, fellows engaged in the V-PLC were very much attuned to the need of the students and their ideas about science. This is also evidenced by another of the core HLPs described by (Windschitl et al., 2012), eliciting student ideas. This HLP could be seen through the engagement of elementary fellows with the use of misconceptions. Elementary fellows witnessed secondary peers eliciting the ideas of their students to identify misconceptions, before using these very misconceptions to align learning activity for the lesson.

Lastly, the data show elementary fellows engaging in practices or conversations about practices that would support students in the last core HLP ‘encouraging students to use evidence-based explanations.” Fellows provided examples of using literacy strategies to their secondary colleagues which ultimately lead students towards the ability to reason or use evidence. The use of cause and effect in a reading assignment serves as a good example of this in the data.
I posit that the interactions reported in the data between the elementary fellows and their secondary peers provides evidence that socially constructed knowledge about science teaching that promotes the three-discourse based HLPs occurred within the V-PLC debrief meetings. This supports the idea that collaboration amongst peers and the community is critical for supporting the use of new practices (Wilson & Berne, 1999). The elementary fellows were socially collaborating with their V-PLC peers, the other fellows in the program, and the leadership of the program.

The importance of setting the foundation in science for students cannot be underestimated in the current NGSS based science education climate. Without this foundation, students will enter the second half of their K-12 school career lacking basic knowledge of scientific concepts and understandings. The science instruction they will receive will be predicated on this missing knowledge and consequentially, students will be at a significant disadvantage. Through observation of middle and high school science classrooms, elementary fellows experienced the vertical nature of scientific language and developed an understanding of how important acquisition of this vocabulary was for their students in future grades. Additionally, middle and high school fellows praised the elementary fellows for the level of vocabulary they saw being used. Elementary fellows also found that they were able to provide support to their upper level fellows with some of the literacy strategies and tools that they used in their science classrooms, for example, the use of word banks or anchor charts for students. Secondary science teachers have little formal training in language use, therefore are less inclined, or lack the awareness or confidence to employ literacy strategies (Lewis, Baker, & Helding, 2015). Elementary fellows also demonstrated strategies for incorporating other literacies strategies, for
example, written expression of vocabulary as a tool for assessment of the student learning and the use of real life experience to complement vocabulary acquisition. One of the core HLPs suggested by (Windschitl et al., 2012) is that of supporting students in sense making. It is clear that the elementary fellows created new knowledge for themselves about using scientific vocabulary and also general academic language and literacy, both of which are critical is supporting students sense making.

A new vision for science teaching and learning, as called for by Windschitl and Calabrese Barton (2016), includes a professional support system within which teachers can develop what Bryk (2009) describes as a shared language and conception of goals and learning supported by common understandings of what constitutes student learning. This is important because Bryk (2009) identifies that the new vision of practice is centered around a social community of learners. Lampert (2010) also describes this construct as being practices which are created and maintained by a community whose membership facilitates learning of the practices. Therefore, it is important to identify that the very nature of the V-PLC model is grounded in the theory of social constructivism, which facilitates knowledge building through social experience.

In the V-PLC model used in this current study, elementary science fellows participated as members of a professional learning community that provided an opportunity for them to share and observe science teaching with science teachers representing the full scope of the K-12 science continuum. During their participation, the elementary fellows discussed, observed, and reflected on the scientific language and teaching practices that they held in common with their secondary level peers. Additionally, they and their peers developed common understandings focused around
supporting student learning in their practice. They used evidence in the form of lesson videos and student work exemplars to develop shared understandings of good science teaching practice. Rather like the model of Japanese lesson study, V-PLCs permit the building of trust and respect amongst peers. In a study examining Japanese lesson study in the elementary science classroom setting, Dotger (2015) presents findings that support the findings of this study. V-PLCs promote a collaborative focus on the aspects of the lesson as opposed to the choices the teacher made. The elementary fellows in this study were socially engaged in a V-PLC which created a safe professional space for them to create new knowledge of their practice, share experiences and expertise with their peers, observe their peers teaching science across the K-12 spectrum and discuss and suggest ways to improve both their practice and the practice of their peers.

In multiple ways, the elementary fellows participating within V-PLCs used their observations and debrief meetings to collaboratively develop understandings of good practices for elementary science learning. The practices which fellows identified or shared essentially play the role of supporting practices to the core HLP (Windschitl et al., 2012) The supporting practices were teaching K-12 scientific language; incorporating misconceptions into science teaching; teaching general language, ELA, and literacy in science lessons; and incorporating feedback and assessment into science teaching. These practices are not new concepts, but the way in which they were identified and created as themes by the elementary fellows certainly supports their importance in elementary level science teaching. That middle and high school level fellows were also involved in the creation of these practices adds to the importance of the practices for student success on a K-12 level.
V-PLCs address three critical components of teacher development, namely, professional, social and personal development (Bell, 2003). V-PLCs are deeply embedded in subject matter, involve active learning, connect teachers to their own practice, and part of a coherent system of support. V-PLC also offer an environment where, elementary teachers are able to experience supportive shared leadership and collaborative learning with a student-needs focused community. In the community, there are shared visions and values focused on student learning, supportive structural and interpersonal conditions, and perhaps most significantly, shared practice.

Implications and Conclusion

Many researchers have advocated an urgent need for supporting and developing better and more clearly defined science teaching practices in light of what we know about the potential for student learning (Blank, 2012; Lampert, 2010; Reiser, 2013; Wilson, 2013; Windschitl & Calabrese Barton, 2016). Roth (2014) proposes that it is important that we support and explore how to provide opportunities for teachers to be “well-started beginners.” In the current NGSS focused environment, I would go further than Roth and suggest that we in the science education community need to both support and explore how to best prepare all currently practicing elementary science teachers to develop, implement and sustain good science teaching practices in their classroom to support the introduction of NGSS guided teaching. Elementary science and science education in general is at a crucial point in this country, especially when considered from the viewpoint that the first seven years of a child’s school experience are foundational in the
K-12 science journey and future science success for students. Elementary teachers need to be prepared, developed, and supported in the science education continuum (Mensah, 2010).

Roth (2014) asserts that there are few studies that examine system-wide supports and constraints for elementary school science teachers, and she also states that there are few studies that examine elementary science teaching practices. In this study, normal, system-wide supports and constraints are challenged, as elementary science teachers are given the opportunity to work with peers from outside of their normal daily context. In this case, the V-PLCs consisted of a mix of elementary, middle and high school teachers from five different school districts. Additionally, the practices of elementary science teaching are also uniquely challenged in this work, as elementary science teachers are confronted with the opportunity to teach in front of, receive feedback from, observe, and provide feedback to both middle and high school level peers from outside of their districts. By challenging the normal school and classroom constraints associated with being a classroom teacher, this study provided elementary teachers an opportunity to cross pollinate.

In conclusion, working as a member of a V-PLC made up of teachers spread across five school districts created a unique and significantly different support structure than a typical elementary science teacher will encounter in their everyday teaching context. One might look at this as a new model for system-wide cross district support. The V-PLC model provides an opportunity for elementary teachers to break out of traditional system-wide constraints and work with respected peers at various levels within the K-12 science teaching continuum across districts.
Chapter VI

FINDINGS

SELF-EFFICACY AND VERTICALLY ALLIGNED PROFESSIONAL LEARNING COMMUNITIES THROUGH THE EYES OF ELEMENTARY FELLOWS

Abstract

It is generally understood in the science education community that various federal policies have effectively marginalized elementary science over the past 16 years. This is principally because of federal policies related to English language arts (ELA) and mathematics that have held states, district and school administrators accountable for improved outcomes in these subject areas. Thus, often the focus in elementary schools has been one centered around supporting success in ELA and math, with other subjects taking a backseat. In addition to this, traditional elementary teacher preparation fails to adequately prepare future elementary teachers to teach science. In part because of the lack of preparation, elementary teachers report a lack of motivation and confidence to teach science. In this exploratory case study, 28 elementary teachers, who are a part of a larger two-year science education professional development program, were studied to explore if and why they found the experience of participating in vertically aligned professional learning communities beneficial. Additionally, the various components and
interactions of the professional learning community were examined for evidence of opportunities to improve self-efficacy. Results indicate that the structure and interactions of the professional learning community provided many benefits to elementary teachers and provided multiple opportunities for teachers to improve their self-efficacy.

**Keywords**: Vertical Alignment, Elementary Science, Self-Efficacy, PLCs

**Introduction**

In a national survey taken by Banilower et al. (2013), only 25% of elementary teachers surveyed felt that they were very well prepared to encourage students’ interest in science. Only 28% surveyed felt that they were well prepared to anticipate student difficulties of misconceptions with certain content areas within science, and only 15% felt that they were very well prepared to support English language learners in learning science. These figures are troubling because today more than ever before a superior science education experience for students in elementary school is critical for future success in their schooling career. Moreover, the concerns around science education at the elementary level have been well documented in the literature and many of the concerns can be directly attributed to district and government policies focused on accountability in English and math, which have had a pointedly detrimental effect on science in elementary school (Blank, 2012; Buczynski & Hansen, 2010; Mensah, 2010).

Another issue that plagues elementary science is that elementary teachers have traditionally been prepared as generalist educators (Kier and Lee, 2017), often spending very little time if any on science teaching during their teacher coursework (Appleton &
Kindt, 1999) and often having an inadequate academic background for teaching science (Lee et al., 2008; Tilgner, 1990; Tosun, 2000). It is not a surprise then, that current elementary teachers exhibit negative attitudes towards teaching science at the elementary level (Abell & Roth, 1992; Appleton, 2013; Avraamidou, 2013; Gunning & Mensah, 2011).

**Literature Review & Theoretical Framework**

In this study, I use the philosophies of social constructivism and self-efficacy theory to explore the experience of elementary teachers in vertically-aligned PLCs (V-PLCs). I examine using the lens of three dimensions from Hord’s five dimensions of successful PLCs (Hord, 1997; Hord & Sommers, 2008). The three dimensions I use are shared vision and values focused on student learning, supportive structural and interpersonal conditions, and shared practice.

This study is based in the context of a two-year program that supports K-12 science teachers with intensive professional development, opportunities to work in professional learning communities (PLCs) with their peers and a culminating final project. When considering the literature on elementary science as described above in the introduction, it is clear that as well as there being systemic issues that negatively impact elementary science, there are also issues that are based in elementary teachers’ attitudes or feelings about teaching science. One theory that looks at attitudes and feelings about teaching is Bandura’s theory of self-efficacy. With this in mind, this study examines how vertically aligned professional learning communities might provide structures to support
elementary teachers’ self-efficacy and increase their personal belief that they can teach science effectively.

**Self-Efficacy and Professional Learning Communities**

The concept of the PLCs or learning communities originates from the business domain, where there was an increasing need within organizations to share, develop and nurture professional knowledge, also known as human capital, in an attempt to promote the building of knowledge, leadership and innovation from within organizations. Learning communities are defined as groups of people that act on an ongoing basis to develop their knowledge of a common interest or passion by sharing individual resources and by engaging in critical dialogue (Wenger, McDermott, & Snyder, 2002). Hord’s commonly used definition describes PLCs as a community of “Five Dimensions.” These are 1) supportive, shared leadership, 2) collaborative learning with a student needs focus, 3) shared vision and values focused on student learning, 4) supportive structural and interpersonal conditions, and 5) shared practice (Hord, 1997; Hord & Sommers, 2008). The authors Feger and Arruda (2008) conducted a review of the literature on professional learning communities (PLCs) and concluded that PLCs can support changes in teaching practice, improve the culture of collaboration and improve teacher focus on student learning.

Self-efficacy is grounded in psychology including the domains of attitudes and motivations. Self-efficacy was developed originally during studies examining personal fears (Bandura, 1977; Bandura, 1997). Self-efficacy has also been applied to teachers’ beliefs and performance (Ashton & Webb, 1986; Ross & Bruce, 2007; Schunk &
Early research examining teacher self-efficacy used quantitative methods, such as Likert Scales (Ashton & Webb, 1982; Gibson & Dembo, 1984; Zee & Koomen, 2016), and other more recent research has used qualitative methods (Carrier, 2009; Flores, 2015; Gunning & Mensah, 2011; Mansfield & Woods-McConney, 2012).

Bandura’s theory of self-efficacy focuses on an individual’s belief about their ability to achieve a specified goal. There are four kinds of interactions that have been shown to enhance perceived self-efficacy. Each of the four interactions are described below:

Mastery experiences are the most influential and provide opportunities for the individual to engage in building mastery status. This experience includes struggling to overcome obstacles, which, when achieved provides a lasting sense of accomplishment. Mastery experiences can occur over a prolonged period, or they may also occur over a shorter time period (Bandura, 1997; Gunning, 2010).

Vicarious experiences involve the observation of a peer being successful in a particular task. For example, observing a colleague’s lesson and seeing a new activity implemented successfully with students. Witnessing a peer’s success in a situation can help increase perceived self-efficacy (Bandura, 1997).

Verbal persuasion can be described as supportive encouragement from a trusted peer or colleague. For example, a co-teacher or other peer within a school providing positive feedback to a teacher about their teaching. The effect of verbal persuasion is even greater when the individual already believed that they would be successful (Bandura, 1997).
Physiological and affective states describe feelings of stress, anxiety, illness, etc. For example, not being prepared to teach science or not having enough time to teach science. Such stressor or anxieties can all negatively influence an individual’s belief in their effectiveness to complete a task (Bandura, 1997).

Self-efficacy has been shown to be a good predictor of teacher behavior (Dembo & Gibson, 1985; Gunning & Mensah, 2011). Additionally, Bandura suggests that teachers’ ideas about their efficacy has consequences on the activities a teacher conducts with students, the way a teacher manages their classroom and how effectively a lesson is presented. As the teacher is considered to be one of the most important factors on student learning (Bandura, 1993; Tschannen-Moran & Hoy, 2001), a low self-efficacy can therefore impact student achievement (Bandura, 1997; Gunning, 2010; Tucker et al., 2005). This study examines how V-PLCs might provide conditions that could support increased self-efficacy in elementary science teachers.

**Research Question**

a) How do vertically-aligned professional learning communities create an environment that supports opportunities for improving self-efficacy?

b) Why do practicing elementary science teachers view the V-PLC model as beneficial for their personal and professional development?
Methodology

This study is a qualitative exploratory case study (Yin, 2013). The context of the study is a two-year program for K-12 science teachers in five geographically local school districts in the North-Eastern United States. Entry into the program is competitive and teachers are payed an annual stipend if they are successful in their application to join the program. Once a teacher joins the program, they are known as fellows. From here on I refer to participants in the study as ‘fellows’. The bounded system (Creswell, 2013) in this study was the program and data was collected from fellow created sources which were created as a function of the program for the sake of better understanding their experiences and perspectives.

For this study, there were a total of 60 fellows who participated in the larger program, in three cohorts of 20 fellows. This study examines the experience of the 28 elementary fellows engaged in the first six months of the two-year program. During this initial six-month period, the fellows worked in assigned groups of four or five fellows. These groups were comprised of high school, middle school, and elementary school fellows. The groups were assigned by the university leadership team, comprising two professors and myself, and organized by the subject area taught. The middle and high school fellows were assigned a group based on their certification. Elementary teachers were assigned a group based on the subject area they indicated an interest in on their application materials. The groups, therefore, were vertically aligned by content area and grade level taught, and they were known as vertically aligned professional learning communities (V-PLCs).
V-PLCs were tasked with observing a video of each member teaching and then conducting an in person or online debriefing session using a set debrief protocol. In total there were 60 V-PLC debriefs. Each of these debriefs were video recorded and both the lesson and debrief videos were shared with the V-PLC members and the university leadership team via a password protected platform. The debrief protocol is prescribed and can be found in Appendix B.

The data that was analyzed included: fellow reflections in monthly reflection journals (Appendix B), fellow reflections post-debrief and videos of V-PLC debriefs, information recorded in the debrief documentation (Appendix C). Additionally, post-debrief reflection forms and post-fellowship surveys which captured fellows’ thoughts about their experiences in the V-PLC were reviewed. By analyzing data from this wide variety of sources I was able to achieve “maximum variation” (Creswell, 2013, p. 39) which provided an important element of rigor to the findings. During my initial round of analysis, I noted common elements that stood out to me. Next, I looked across the various data sources and grouped these common elements into themes. This process followed with the process of open coding as described by Corbin & Strauss (2008). Next, collapsed themes that shared many similarities, or that could be classified under a broader and larger theme, following the guidelines of axial coding (Corbin & Strauss, 2008). The themes were then further “fleshed out” (Merriam, 2009, p. 182) by several more examinations of the whole data set. The amount of data examined and the time period that the study occurred over provides the basis for a rigorous study (Creswell, 2007).
Findings

In this section, I present the study findings under the major themes that emerged during data analysis. If appropriate, descriptions that contextualize or connect the data to the theoretical lens accompany the data.

Positive Impressions of V-PLCs

One indicator of the success of the V-PLC for elementary fellows can be seen in the post fellowship survey that elementary science fellows were asked to complete. Responses to the V-PLC experience were unanimously positive. After completing the two-year fellowship, fellows made very powerful statements about their experiences in the V-PLC on their post-fellowship surveys. For example, Peyton, an elementary fellow, talked about the personal development she felt she had experienced as part of a V-PLC:

In terms of my personal development, having the opportunity to observe other teachers and to give and get feedback is always a positive experience. The V-PLC process allowed me to grow as a reflective teacher. Collaborating with teachers at the middle and high school level is an opportunity that is far too rare for teachers all across K-12. (Peyton, Elementary Teacher, Cohort 1)

Peyton also talked positively about her experience from a professional perspective:

In professional terms, it was a powerful learning experience to see the same science topic taught across K-12. It was beneficial to see how my students would be building upon the science learning they were doing at the elementary level, and it also stressed the importance of being vigilant about teaching enough science at the elementary level. (Peyton, Elementary Teacher, Cohort 1)

Other elementary fellows also felt just as strongly about their V-PLC experiences. Elementary fellow, Althea, stated:
The V-PLC was extremely powerful for me. I found working with this group of teachers more informative than working with teachers from my own age group. I was able to see how my teaching now impacts my students’ future in science and understanding and learning. I was able to speak with colleagues and learn about their teaching methods and styles. I was able to see the different ways to engage students at all age levels. In addition, having the opportunity to speak with the teachers about their teaching style is beneficial. It exposed me to different ways of reaching students at all academic and age levels. (Althea, Elementary Teacher, Cohort 2)

It is important to note that the post-fellowship survey responses of the elementary fellows were complete one and a half years after participation in a V-PLC. Based on their statements, it is apparent that the impact of the V-PLC felt by the elementary fellows was more than short term.

**Trust and Respect**

Trust and respect are critical components of science teacher PLCs that have been reported previously in the literature (Fulton, Doerr, & Britton, 2010; Richmond & Manokore, 2011). Similarly, the fellows developed a significant amount of trust and respect for one another. When fellows first enter the program, they can often become a little overwhelmed by the amount of work that they are being asked to complete on top of their normal teaching load. This is the point of the program during which fellows enter into their V-PLCs and are engaged in their first experience of video observations and feedback as a team. This can be a particularly challenging time for fellows, but it is clear that a culture of trust and respect amongst the vertical teams is quickly established. Developing trust and respect is really important because it allows the fellows to feel at ease with the process while providing a safe space to share and receive feedback amongst their peers.
There are multiple examples in the data of upper level fellows sharing their respect and admiration for elementary peers during debrief meetings. Some example of this include, Daniel, a cohort 1 high school fellow, who following a debrief of a sixth-grade peer’s lesson, stated to his V-PLC: “I appreciate that this has given me the opportunity to observe a science class in a different grade, and discuss it with you all, colleagues I have quickly grown to trust and respect.” Daniel, also found himself impressed by how hard elementary teachers work to include science. Daniel stated to another elementary peer, Peyton, after her lesson debrief: “After this debrief, I got a sense of how hard elementary teachers have to fight sometimes to include science in their teaching practice.” The work level of elementary teachers was also acknowledged by other peers. In another example, Wendy, a high school teacher, shared with her elementary peer, Kathy, “I saw how intense the challenge is for elementary teachers, when teaching students who need more direction than middle and high school students.”

Many elementary fellows found the feedback provided to them during V-PLC debrief to be supportive, encouraging and useful for their own practice. In one such example of this, Grace, an elementary fellow from cohort 1, wrote the following in her post-debrief notes:

The feedback from my peers on my lesson was helpful and welcome. I was pleased with the video and response to my lesson. I was happy to know that other upper-level science teachers approved of the science content. The debrief of my lesson was most helpful and it was really useful to hear what others picked up/thought about the lesson. (Grace, Elementary Teacher, Cohort 1)

Another elementary fellow, Ethan, also found the experience to be extremely useful and supportive. After debriefing on his lesson, Ethan wrote the following in his post-debrief reflection log:
I am very grateful for the feedback I received. Hearing the warm feedback bolstered my feeling that I am heading in a good direction. The cool feedback gave me a lot to ponder in terms of creating stronger science lessons which tie in reading and writing. (Ethan, Elementary Teacher, Cohort 1)

In the data, there were additional examples of elementary fellows finding the experience to be beneficial. Elementary fellow, Lily, wrote in her post-debrief reflection: “So proud that my group was impressed by how my kids worked and behaved.” Piper, another elementary fellow, wrote in her post-debrief reflection: “I am definitely harder on myself than my peers. They were all very complimentary!” Leona, also an elementary fellow, who wrote in her post-debrief reflection:

I appreciated the wide range of warm and cool feedback and how thoughtful my colleagues were. Constructive peer review and commentary on our lessons is a really valuable tool for effective instruction especially when in a vertical group like this where you get a wide range of perspectives. (Leona, Elementary Teacher, Cohort 2)

Other elementary fellows commented about the positive impact of observing and discussing lessons taught by their peers. For example, Kathy, an elementary fellow, reflected after the debrief of her middle school peer, Mia. She wrote: “Our discussion of how we could use Mia’s insights of her students to enhance our practices and by extension improve the learning of our own students was powerful for me.” In another debrief, Ethan, an elementary fellow, wrote the following about the debrief process for his elementary fellow Zoe’s lesson: “It was most helpful to listen to my co-fellows input. They all came in with different experiences and ideas which resulted in a rich discussion.” In another example, Zoe, an elementary fellow, wrote the following reflection after debriefing her lesson:

I feel that the feedback was very positive and reminded me that teaching elementary school students affords many opportunities for growth and deep learning. It was a bit scary to have peers evaluate and critique your work yet, they
were so positive and affirming that it was beneficial. (Zoe, Elementary Teacher, Cohort 1)

Fellows all seemed to genuinely value receiving feedback from their V-PLC colleagues. More so, they seem to have valued the feeling of respect and trust that became apparent between the various levels of fellows in each group. When considering the data in this theme from the perspective of self-efficacy, one sees that the elementary fellows were experiencing vicarious experiences, as they observed their peers teaching and discussed the ways in which the successes they saw impacted students or could be used in their own individual classroom context. Additionally, many elementary fellows reflected on how happy they were to receive praise or support from their secondary peers. This is a classic example of verbal persuasion, where a trusted peer or mentor provides encouragement or praise. The positive feelings reported by fellows in the data also indicate that there may be positive affect for the elementary fellows participating in these V-PLCs. One post-debrief reflection written by Daniel, a high school fellow, stands out as a marvelous summary of the feeling of trust and respect that was established during the V-PLCs. Daniel wrote:

This is the best type of professional development, because it is a sustained effort with trusted colleagues, instead of a one-shot deal from an expert who may or may not understand our particular situation. (Daniel, High School Teacher, Cohort 1)

The Value of Peeking into Another Level Science Classroom

Many elementary teachers (1 out of 4) do not have access to collaborate with their peers during the working week (Windschitl & Calabrese Barton, 2016). The vertical nature of the V-PLC makeup provides a unique opportunity for fellows to look into a
classroom and observe science teaching at a very different level to their own practice. In the data, there are many examples of fellows acknowledging this opportunity and describing the positive impact of seeing their peers in practice. For example, Peyton, an elementary fellow, wrote the following reflection after debriefing Daniel, a high school fellow:

As a result of the debrief, I was able to see how the dynamics of a high school advanced placement chemistry class work. The way the students were encouraged to explore their initial misconceptions and then modify their thinking based on demonstration and group discussion was powerful for me. (Peyton, Elementary Fellow, Cohort 1)

This reflection from Peyton is a very good example of a vicarious experience. Peyton was able to watch a high school teacher teaching a chemistry class and learn about how he used a particular practice successfully. In this case, Peyton observed Daniel using misconceptions to promote student thinking. Additionally, Peyton alludes to this observation being personally important in her reflection.

In another example, after debriefing a high school peer, Lily, wrote in her reflections: “Watching Ruby, I got some great ideas on how I could check in with my students to check on their understanding of directions.” One other example come from Kathy, an elementary fellow. After debriefing her high school peer, Leah, Kathy wrote the following reflection:

It was really helpful as an elementary teacher to watch the video of a high school teacher experienced in using open inquiry and then being able to ask questions as to how she instituted the protocols and procedures that support student work. (Kathy, Elementary Teacher, Cohort 1)

Here, Kathy observed a upper level peer successfully using inquiry in their classroom, gained useful knowledge, and asked this peer questions. This is another example of a
vicarious experience and the use of a V-PLC to socially construct knowledge about high quality teaching practices that could be incorporated into the individual’s own classroom.

Caleb, a cohort 1 elementary fellow, also appreciated the opportunity that observing a teacher from another grade level afforded him. After observing and debriefing Chloe, a middle school fellow, Caleb wrote the following in his reflection:

I was very impressed with the organization witnessed in observing Chloe’s middle school class. As an elementary school teacher, I have the luxury of time, but Chloe showed me that I can be much more efficient and much more authentic in my teaching. (Caleb, Elementary Teacher, Cohort 1)

This is another example of an elementary fellow having a vicious experience with an upper level peer.

A particularly illuminating summary of the appreciation fellows felt for the V-PLC process can be found in the post-debrief reflection writing by Zoe, an elementary fellow. In her reflection, Zoe wrote: “Since we can’t actually visit each other’s classrooms this vertical alignment has allowed us to peek into other grades, other schools, other classrooms. This has been most useful for me.”

Another benefit to peeking into another classroom reported by fellows, was being able to observe a variety of high quality, engaging science teaching across variety of levels and contexts. Peyton, wrote the following about observing her middle school peer: “I observed good teaching practices (strong vocabulary, student engagement, goals clearly outlined, strong modelling).” Caleb reflected after watching Mia’s middle school lesson: “What was most helpful was seeing Mia in action was her enthusiasm, such a strength, was contagious and made her lesson exciting. I wanted to be there.” Caleb also wrote about his experience observing Peyton, an elementary peer. In his reflection, Caleb wrote: “I enjoyed the opportunity to see Peyton’s question techniques and wonderful use
of visuals and organizers definitely had me taking notes.” Peyton, in turn, had positive things to say about observing Caleb’s lesson: “It was particularly helpful for me listening to how Caleb questioned student’s observations as a means of promoting deeper understanding.” The vicarious experiences here are recorded frequently in the data and occur with both secondary and elementary level peers.

One more example in the data is seen in Lily’s reflection after debriefing Piper, an elementary peer. In her reflection, Lily wrote: “As a result of this debrief I am really going to try and come up with fun, engaging experiences, that my students will remember. I also won’t underestimate the ability of 2nd graders.” Here we see a vicarious experience impacting the attitude of an elementary fellow, Lily. Lily not only has a positive attitude towards incorporating something she observed into her classroom, but she gets the sense reading this that Lily is reinvigorated and excited at the prospect of using some of these new ideas. Accordingly, the social nature of knowledge generation through interacting with other peers and observing their success (a vicarious experience), can also be considered to be a positive result of this V-PLC.

The V-PLC Experience as Personally and Professionally Beneficial

After completing two years in the fellowship, fellows were asked to consider their time in the fellowship and provide reflections based on a series of question prompts. Several of these prompts were directly related to the V-PLC component of the first year in the fellowship. Here, I use responses to the V-PLC specific prompts completed by elementary fellows to create a representation of the longer-term impact of the V-PLC model on elementary fellows as seen through their perspective.
Elementary fellows' reflections and writing about their experiences showed enormous benefits on a personal level. For example, Peyton wrote the following in her reflection:

Having the opportunity to observe other teachers and to give and get feedback is always a positive experience. The V-PLC process allowed me to grow as a reflective teacher. Collaborating with teachers at the middle and high school level is an opportunity that is far too rare for teachers all across K-12. (Peyton, Elementary Teacher, Cohort 1)

In another example, Ella, indicated how valuable the experience was for her:

It was helpful to see what others experience in the different grades. In talking to others in my group, I was able to share my perspective and hopefully some advice or insight with any issues or ideas that I had. (Ella, Elementary Fellow, Cohort 3)

Zoe, asserted that the vertical attributes of the V-PLC experience were overwhelmingly positive from her personal perspective. In her reflection, Zoe wrote:

This was a very positive experience. Met some really great teachers from different schools and districts. Had the opportunity to really think about science content and how it's delivered at different times in a student's life. Our group was very supportive and interested in working together. (Zoe, Elementary Teacher, Cohort 1)

Althea also found the vertical nature of the experience to be personally very useful. In her reflection, Althea wrote:

I found working with this group of teachers more informative than working with my own age group. I was able to see how my teaching now impacts the students' future science and understanding and learning. (Althea, Elementary Fellow, Cohort 2)

Elementary fellows also reported that they found the experience of the V-PLC to be professionally powerful, positive, and enlightening. Peyton identified that the opportunity to learn about the journey that her students would take, and the expectations that would be held of them, made her reconsider the importance of teaching science at the elementary level. Peyton wrote:
It was a powerful learning experience to see the same science topic taught across K-12. It was beneficial to see how my students would be building upon the science learning they were doing at the elementary level, and it also stressed the importance of being vigilant about teaching enough science at the elementary level. (Peyton, Elementary Teacher, Cohort 1)

Zoe, discovered the value of learning about the content and concepts that students would learn as they progressed K-12. Zoe also identified that she felt it was beneficial for her middle and high school peers to know more about the science that is covered at the elementary level. In her response, Zoe wrote:

Having the chance to think about science content and the actual teaching of the concepts at different age-levels was fascinating and enlightening for all. As an elementary teacher, I was able to see where the students were going with the concepts. The middle and high school teachers were able to see how the concepts were introduced to younger children. What prompts, visual, hands-on experiences helped to build their knowledge base. (Zoe, Elementary Teacher, Cohort 1)

Faith, found that the vertical grouping provided a valuable reminder that feedback on teaching from perspectives at different levels within the school system was really important to her. Faith wrote: “The experience reminded me about the importance of getting feedback from different perspectives.” Althea wrote about what it meant for her to talk with peers from different grade levels:

Professionally, I was able to speak with colleagues and learn about their teaching methods and styles. I was able to see the different ways to engage students at all age levels. In addition, having the opportunity to speak with the teachers about their teaching style is beneficial. It exposed me to different ways of reaching student at all academic and age levels. (Althea, Elementary Teacher, Cohort 2)

Ella felt the professional benefits of the V-PLC were the sharing of ideas and materials, as well as the insights of multiple peers at different levels in the school system:

I was able to get a lot of ideas, lessons ideas and materials that I could use in my classroom. It was helpful to get a variety of insights and how my group approached things in different ways. (Ella, Elementary Teacher, Cohort 3)
The data showed that elementary fellows who participated in a V-PLC gained personally through reflections and conversations with peers. Data also provided evidence that V-PLCs provide elementary fellows with the opportunity to learn about science content through the school system and what their students would need to be able to do as they moved up grades. Additionally, fellows found that engaging with V-PLC peers provided them opportunity to learn about different approaches for engaging students and have discussions about methods and materials.

The V-PLC for Validation and Making Connections

Other ways fellows reported being impacted by the V-PLC model included feeling validated by interacting with teachers at higher grade levels. A powerful example of this was shared by, Peyton, from cohort 1. In her survey response she wrote:

The responses from my colleagues teaching at the middle and high school level was very validating; many of the elementary fellows received similar feedback on how teachers at the middle and high school level underestimated the capabilities and content knowledge that elementary students have. (Peyton, Elementary Teacher, Cohort 1)

Another impact of the V-PLC model that elementary fellows reported is that of being able to make connections with fellow teachers in different districts. For example, Abigail, a cohort 3 fellow, wrote the following about her experiences:

The most important part of the V-PLC for me is making the connections with teachers from other districts. It is difficult to do something like that unless it was a professional development or meeting that I needed to attend. While working in my V-PLC it allowed me to make these connections and I learned from experienced teachers and heard what they do in their schools. (Abigail, Elementary Teacher, Cohort 3)
Other elementary fellows reported that they found the experience to be invaluable because of the feedback and support they received from their V-PLC peers. For example, Zoe, wrote about feeling that her peers validated her work through the process of warm and cool feedback. Warm feedback is complimentary in nature and praises or congratulates fellows for successes observed. Cool feedback is constructive in nature and may take the form of questioning or advice. In her reflection Zoe wrote:

Even though it was a bit nerve-wracking at first, the filming and debrief meetings. You really need to buckle down and walk the walk, not just talk the talk. Many teachers claim to do this and do that when teaching but you really get to see what you are doing; the students are doing (and not doing) when you film your lesson. Having the critique from V-PLC members was also an anxiety laden event but with the protocol of warm and cool feedback, it became constructive and safe. (Zoe, Elementary Teacher, Cohort 1)

Grace, also reported the positive impact receiving feedback in the V-PLC model. In her reflection, Grace wrote:

Watching videos and offering feedback was the most important thing for me. It made me see teaching in real-form and not so scripted. This made me feel more confident in my teaching. (Grace, Elementary Teacher, Cohort 1)

Benefits of Vertical Alignment

“I loved seeing how we all taught the same thing but at different levels.” (Lilly, Elementary Fellow, Cohort 2)

The elementary fellows found the vertical experience to be highly beneficial. Ways that fellows found the vertical alignment to be beneficial have already been mentioned in the previous themes. These included but are not limited to, the value of feeling trusted and respected by their middle and high school level peers, the opportunity to see high quality science teaching at middle and high school levels, the opportunity to
learn more about what their students will be expected to know at in science as they move through the school system, and the opportunity to connect with and feel valued by their middle and high school peers. There are however, several examples that do not fit into these aforementioned themes, in which fellows explicitly identifying the vertical nature of the grouping and discuss the advantages of this. For example, Kathy, wrote the following in a post-meeting reflection: “I found the vertical discussion about the science content and the understanding that we are all trying to get our students to be better learners to be most useful.” Whereas, Piper found the vertical nature of the groupings useful for refreshing her content knowledge. Piper wrote the following reflection after debriefing her high school peer, Ruby: “This lesson debrief I learnt about photosynthesis and starch! I had forgotten most of these concepts!”

One example of elementary fellows explicitly referencing the vertical benefits the V-PLC, is seen in a post debrief reflection written by Zoe,. Zoe had just debriefed her high school peer, Sarah, and wrote the following:

The vertical connection was expanded here through using the same topic through 2nd-5th – 6th-7th and high school. Working with the same topic allowed us to see the connections across grades. (Zoe, Elementary Teacher, Cohort 1)

In another example, during a cohort 1 V-PLC debrief, Peyton, an elementary fellow, stated to Daniel, a high school fellow:

It is interesting to see that, no matter what grade we teach, students are still the same students and the have some of the same questions. Even if the level is much higher, the process can still be remarkably similar. (Peyton, Elementary Teacher, Cohort 1)

One other example from the data, comes from another cohort 1 V-PLC debrief. In the debrief, Daniel, a high school fellow, stated to Caleb, an elementary fellow:
One thing that this meeting helped me remember is that some of the challenges of teaching are the same for us all, no matter what grade we teach, and that teachers from other grades have some very keen insights when they have a chance to see what you do in your own classroom. (Daniel, High School Teacher, Cohort 1)

Discussion

Positive Impacts of V-PLCs and Opportunities for Improved Self-Efficacy

I begin this section by quoting reflections from two elementary fellows. The first reflection is from the post-fellowship survey completed by Althea. In her reflection, she writes: “In elementary school we are teaching the foundation to student science understanding. Without it they will have huge gaps created.” The second reflection comes from Zoe, who wrote the following reflection after her V-PLC debrief:

We need to push for more science instruction in elementary school to help promote science writing and thinking. When we limit science instruction in elementary school, we also limit opportunities for thinking and writing. (Zoe, Elementary Teacher, Cohort 1)

I quote these two fellows because they provided a very important reminder to the true value of this work. The program as a whole, provides a unique, special and beneficial opportunity for K-12 science teachers to socialize, collaborate, share knowledge, build knowledge, and grow both personally and professionally. Yet, these two quotes remind us that the goal of this program is to help teachers improve in their practice so that they can better support their students in the learning of science. As a leader and researcher in this project, it makes me very happy to see that the teachers in this program understand the bigger picture and feel comfortable enough to share their true feelings.
The evidence presented through the views of the elementary fellows, shows there are multiple positive impacts associated with the V-PLC model. As a researcher who has worked closely with the fellows for the duration of the fellowship, and who has spent a significant amount of time analyzing data for the study, I see several clear benefits, but also several distinctive challenges that the V-PLC model provides, and I summarize these below.

Firstly, it is shown across all of the data that elementary fellows gain significant personal and professional development from the social support network of peers who belong to the V-PLC and the larger fellowship. Elementary fellows feel good about their work, gain self-confidence about what they are doing in their classrooms, gain a sense of community, and develop mutual trust and respect within their V-PLCs. Bandura would refer to this as evidence of vicarious experiences, verbal persuasion and positive influences on affective states.

In the data, elementary fellows are excited by the opportunity to learn about what science looks like for middle and high school students and teachers. Additionally, elementary fellows report that they find it very useful to see what the expectations are for science content at the middle and high school levels. This is critical because it grounds elementary fellows in the continuum of science education and it illustrates to them the importance of high quality science teaching at the elementary level.

Secondly, the study also shows that when elementary fellows were engaged in their V-PLCs, they demonstrated a real desire for personal and professional growth. This desire for growth provided motivation for their V-PLCs to spend time focusing on
identifying practices and pedagogy that can support their own elementary science practice and facilitate better student support in science learning at the elementary level.

Banilower et al., (2013) identify that only 25% of elementary school teachers believe that they have control over course content and goals. In many ways, the data shows that the V-PLC experience can function to re-professionalize elementary teachers by assisting elementary teachers’ responsibility for developing and supporting high quality elementary science education. Their teacher peers across multiple grade levels were instrumental in this process of teacher knowledge generation and peer-peer support of high quality science teaching practices that support student learning. This was also combined with multiple examples of opportunities for vicarious experiences, verbal persuasion and positive influences of affective states. V-PLCs can provide elementary teachers a multitude of structures that can support self-efficacy. The elementary fellows in this study self-reported many positive reflections that indicated that they had a high level of self-confidence about their ability to be successful in the teaching of science at the elementary level.

**Implications and Conclusion**

I have personally witnessed the immensely positive responses of elementary fellows when they participate in the V-PLC model. This enthusiasm can also be seen in the findings of this study. The findings indicate a broad range of positive outcomes and interactions that the elementary fellows experience in a V-PLC. Yet, the most important
piece of this work is what these elementary fellows take into their classrooms in support of their students’ learning of science.

There is a critical need to provide elementary teachers with the kinds of personal support offered by the V-PLC model because of the ongoing implementation of NGSS which will necessitate students entering middle school to possess a broad knowledge base of science. One way of thinking about this may be to consider the repositioning of the university teacher educator/support faculty. The V-PLC model provides effective opportunities for teachers to develop supporting communities that share practice, so perhaps in future iterations of such a model, university faculty may consider taking a role that is more structured around guided support that assesses and validates the knowledge being generated at a local level. This would ensure that the progressions of scientific knowledge expected in NGSS are understood at all levels of the K-12 science system.

Additionally, elementary teachers in particular would feel that they have a supportive environment to build their knowledge. These educators would also gain confidence in their ability to teach science that is correctly aligned with what their students will need to know in order to progress successfully in middle school science and beyond. While this is a critical requirement for districts or states adopting NGSS, it also makes sense for school systems that align their science curricula to progressively build student knowledge in science over time.

Bandura (1997), suggests that the confidence of an individual is a measure of one’s self-assessed ability to perform the task as well as the individual’s expectation that performing the task will result in a positive outcome. If the confidence and excitement of the elementary fellows as seen in the data is any indicator of their self-assessment of
ability to be successful, the V-PLC model should be considered to be extremely beneficial to elementary teachers looking to grow in their science teaching.
Chapter VII

DISCUSSION, IMPLICATIONS AND CONCLUSION

Introduction

The purpose of this study was to explore elementary teacher experiences as participants in a vertically-aligned professional learning community (V-PLC). The underlying issue in the context of the study was the implementation of a new set of science standards, the next generation science standards (NGSS), which increases the importance of high quality science instruction in elementary schools and may lead to mandates for more science instructional minutes at the elementary level. Because of the traditional issues with elementary science teacher preparation and federal policies that have unintentionally pushed time for science aside in elementary schools, there is a pressing need to find effective methods to support elementary science teachers’ implementation of the NGSS. The study examines key components for providing improved elementary science instruction, such as learning to support student success, developing knowledge of effective practices which support core science teaching practices, and examining the V-PLC model for ways in which it can support improving efficacy in current elementary science teachers. Additionally, the study explored how elementary teachers viewed the benefits of V-PLC participation.
Summary of Major Findings

There are four major findings of this study that relate to the importance of the V-PLC model for elementary science education.

First, V-PLCs provided opportunities for elementary fellows to work with secondary grade-level fellows to socially construct knowledge and develop their pre-existing knowledge of ways to support student success in the elementary science classroom.

Second, contrary to the findings in the literature, elementary teachers in this study were actively engaged in supporting student understanding in science. Indeed, in many cases elementary fellows provided insight to secondary fellows as to how literacy skills could be incorporated into a science classroom to support literacy. V-PLCs provided elementary fellows the opportunity to observe, learn from and socially construct knowledge of practices that support the core practices identified by (Windschitl, Thompson, Braaten, & Stroupe, 2012). They were able to do this in a supportive environment that provided them the opportunity to observe teaching outside of their normal grade level and district contexts.

Third, the V-PLC model provided structures that were well placed to support an increase in the self-efficacy of the elementary fellows. Additionally, there were multiple examples of interactions in the data that indicated vicarious experiences, verbal persuasion and positive influences on affective states.

Finally, there was an overwhelmingly positive impact identified by elementary fellows from socializing with their middle and high school level peers. The elementary
fellows reported feeling good about their work, gaining self-confidence about what they are doing in their classrooms, gaining a sense of community, and develop mutual trust and respect within their V-PLCs. These strong and supportive relationships were essential for helping elementary fellows develop self-confidence in their abilities to teach science. It is clear that the relationships formed between secondary and elementary teachers during the V-PLC substantially increased the elementary teachers’ self-confidence to teach science, as well as their knowledge of why the science they were teaching was so important for their students.

**Findings Across Chapters**

In this section, broad themes across the three studies will be discussed. In the findings of the three studies there is much evidence to show the benefits of aligning PLCs vertically. I believe that this evidence provides an accurate documentation of the all-round benefits of V-PLCs. In my time as a member of the leadership team and as a researcher working in the program, I became enormously cognizant of the personal and professional impact that being a member of a V-PLC afforded participating elementary fellows. In the final study (Chapter VI), one can see the impact of the V-PLC reported in the words of the elementary fellows. It is powerful to read how much this experience meant to them and the impact they see it having in their everyday classroom settings.

One aspect of the V-PLC experience which must not be overlooked is the power of video. Video is a very useful form of data because it captures the actual occurrences as they happen, including non-verbal behaviors and communications (Merriam, 2009). This
is of particular value not only to the researcher in an archival sense, but also to the fellows within the V-PLC who are able to observe real time occurrences in their peer’s science classrooms. Consequently, fellows have the opportunity during the V-PLC periods to learn and grow in their practice through observing their peers’ video recordings, listening to the reflections and feedback of their peers based on the video recordings, and providing their own constructive insight into their peers teaching.

Another benefit of V-PLCs and the benefit of video is that teachers are able to engage which other teachers from the K-12 spectrum. This is really important as we know that “‘teachers hold fellow teachers’ expertise in high regard more so than outside experts whom they often see as removed from the day-to-day realities of classroom teaching”(p. 827) (Sandholtz, 2002). The nature of the V-PLC is one of peer-peer support, which greatly adds to the value of the experience.

**Connecting Vertical Alignment in the V-PLC to the NGSS**

One critical and essential aspect of the V-PLC is the vertical alignment of the V-PLC groups. This alignment is intentionally so. The NGSS lays out the expected progression of scientific knowledge for K-12 students, essentially requiring adopting school districts to develop vertically aligned curriculum and teaching practices. The power of the V-PLC as identified by the fellows in the data is directly linked to this vertical alignment. Elementary fellows identify how important it is for them to see the expected future pathway for the students. This process, they report, permits them to ground their practice in the piece of the journey that they are responsible for. Also, this allows the elementary fellows to socially identify common understandings, expectations,
language, and practices with their middle and high school peers. Thus, developing the basis for a smoother transition for students as they progress along the NGSS continuum.

The V-PLC provides a place for peer-peer interactions and the building of professional capital about best practices for teaching science K-12. Elementary fellows also feel appreciated and respected and develop extremely strong relationships with their upper level peers. One high school fellow actually developed a model for elementary teacher professional development in her district based on the experiences she had in the V-PLC where she developed an understanding of the importance of good elementary science.

The V-PLC model has potential to be used in a K-12 setting, a K-middle school setting or even a K-6 setting. However the V-PLC is arranged, facilitating elementary fellows to develop a better understanding of disciplinary content, science and engineering practices, and cross cutting themes and how these will grow and develop over the student projected journey is critical for supporting elementary teacher growth and development in science teaching. Many of the things that elementary teachers do well in their practice are a good fit for high leverage science teaching practices. In turn, the high leverage practices are well positioned to support the NGSS science and engineering practices. Thus, facilitation of V-PLCs for elementary and/or middle and/or high school teachers allows for a very positive impact on the teaching of science at the elementary level. Districts should consider the V-PLC model for future NGSS related professional development and not worry if they are unable to involve all three levels of their schooling system.
Student Success

Across the three studies, it is clear that many of the interactions between fellows focused on supporting student success in science. During V-PLC debrief meetings, elementary fellows identified, discussed and received feedback about student success. This included references to evidence of student learning and engaging students with different modalities and techniques. Fellows also considered these ideas from the perspective of their own practice and from the position of an outsider looking into a peer’s classroom via video.

Elementary fellows also identified many different ways that student understanding can be enhanced during learning. Fellows identified and discussed ways to check for student understanding and considered and reflected on ways they would like to incorporate student understanding in their daily practice.

Many discussions between elementary fellows and their upper level peers also focused around reflections on developing and increasing their understanding of student thinking and reasoning processes. Fellow thoughts and feedback included references to allowing students to struggle with the thinking process, allowing opportunities for student to re-think their initial ideas, using discussion to prompt and develop student thinking, using evidence, and building consensus. There was a lot of discussion and reflection around the use of questions to support student thinking and understanding. Fellows identified several important effective ways in incorporate questioning into their teaching. These included, listening to student discussion and using probing questions, using questions to promote deeper understanding in their students, and using questions to demonstrate student learning or level of understanding. In addition to this, fellows
considered how they could incorporate good questioning into their teaching and pointed out important areas to consider, such as, do students have pre-existing knowledge of what a question is or background knowledge of how to create one?

It is critical that elementary fellows were able to observe science teaching in a variety of grade levels in the V-PLCs. Not only were they able to learn about what science looks like for their students in their future school pathways, but they were also able to improve the chances of a student’s future success in science, by drawing on shared profession knowledge, values, and skills to engage students in ways productive to learning (Loewenberg Ball & Forzani, 2009).

Science Teaching Practices

In their V-PLCs, fellows focused a great deal of their discussions and reflections on K-12 scientific language. The knowledge they collaboratively established included understanding the importance of the vertical nature of scientific language and how they could support and develop this in their teaching. Additionally, fellows discussed how to effectively use scientific language in the elementary science classroom. Ideas included providing introductions to vocabulary prior to lessons, displaying relevant scientific vocabulary in the classroom, holding student accountable for using scientific language in explanations, the use of a word bank and anchor chart, and using scientific language to reinforce reading and writing practices. Another finding in the data identified fellows discussing the use of scientific language to support non-English speaking students in the science classroom and incorporating literacy and scientific language skills. Fellows
discussed holding students accountable for scientific language use in academic talk and questioning.

The data showed that fellows focused several debrief discussions on knowing and anticipating misconceptions when preparing and planning elementary science instruction. Furthermore, fellows considered how to incorporate misconceptions into science classes as a guide for the teaching of accurate concepts and a way to support students developing accurate understandings of these concepts.

Fellows identified the power of using science to support general language literacy skills. They discussed incorporating science instruction to support such ELA skills such as using evidence to support a claim, learning everyday non-science vocabulary, and practicing non-fiction reading.

Finally, the data showed evidence of fellows discussing, providing feedback on and reflecting on the use of feedback and/or assessment to guide or impact a science lesson. Fellows identified several different modes for using feedback and assessment to guide and impact their teaching.

When implementing new teaching practices, the authors Lewis, Baker, & Helding (2015) noted that teachers adapted it to suit their own context and beliefs. One advantage of the V-PLC model is that elementary teachers are not only are able to experience science teaching focused around a new approach or practice in the context of a secondary level classroom, but, they can also experience a peer implementing this within a different context, be that a school district, school, classroom make up, or instructional style. This cross-pollination provides a powerful experience in which elementary teachers can
socially generate personal knowledge about new practices or approaches to teaching science.

**Connecting the High Leverage Practices and NGSS**

In the data presented in chapters four and five, it can be seen that various foci of the fellows centered around ways to better support student success in the science classroom. Additionally, there are many examples where fellows discuss. They also share experiences and knowledge about beneficial teaching practices. As identified in the discussion section of chapter five, elementary fellows were actively involved in discussing and developing knowledge about supporting student sense making, eliciting student ideas, and encouraging students to use evidence-based explanations. These represent three of the high leverage as practices (HLPs) identified by (Windschitl et al., 2012). It is very important to identify that these HLPs connect to the science and engineering practices (SEPs) of the NGSS. Indeed, many of the SEPs are directly supported by the HLPs. Thus, the elementary fellows discussed, built knowledge of, used and developed their practical skills with these HLP, and that supporting practices is very encouraging for the implementation of the SEPs in elementary school. It also demonstrates how effective V-PLCs can be for supporting the development of NGSS instruction at the elementary school. Lastly, it shows that amongst the majority of the elementary fellow participants, high quality teaching practices in science were embraced, viewed as important in the elementary classroom, and seen as achievable through the mutually respectful interactions in the V-PLC with the K-12 peers. Table 7.1 shows SEPs
and some findings from the data that show the connection between fellow discussion of effective practices and the HLPs.

Table 7.1 – Science and Engineering Practices and Connected High Leverage Practices as Seen in the Fellows Data.

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>High Leverage Practice and Chapter in which Supporting Data Identified</th>
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<tbody>
<tr>
<td>Asking Questions and Defining Problems</td>
<td>Eliciting Student Ideas</td>
</tr>
<tr>
<td>Developing and Using Models</td>
<td>Chapters 4 and 5</td>
</tr>
<tr>
<td>Planning and Carrying Out Investigations</td>
<td>Eliciting Student Ideas</td>
</tr>
<tr>
<td>Analyzing and Interpreting Data</td>
<td>Chapters 4 and 5</td>
</tr>
<tr>
<td>Using Mathematics and Computational Thinking</td>
<td>Not identified</td>
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<tr>
<td>Constructing Explanations and Designing Solutions</td>
<td>Discussing and Developing Knowledge About Supporting Student Sense Making</td>
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<td></td>
<td>Chapters 4 and 5</td>
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<tr>
<td>Engaging in Argument from Evidence</td>
<td>Discussing and Developing Knowledge About Supporting Student Sense Making</td>
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<td></td>
<td>Chapters 4 and 5</td>
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<tr>
<td>Obtaining, Evaluating, and Communicating Information</td>
<td>Eliciting Student Ideas</td>
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<td></td>
<td>Chapters 4 and 5</td>
</tr>
</tbody>
</table>

Positive Benefits and Opportunities for Improved Self-efficacy

The data supporting positive benefits of V-PLCs is prevalent across all three studies. The elementary fellows found the experience extremely beneficial both personally and professionally. Central to this success seems is the establishment of trust
and respect amongst the elementary, middle and high school peers, and a feeling of community based on a shared purpose that was established early on by the V-PLCs. When the V-PLCs are first established, it is very common for the leadership team to field nervous questions and concerns about whether an individual elementary teacher is going to be able to ‘cope’ in a V-PLC. This occurs very early in the process, but after the first debrief, these concerns disappear. The feeling of belonging is so strong that even several years after participation in a V-PLC, fellows (K-12) ask if they can participate in their V-PLC again. Similarly, we often learn that V-PLC team members are working on projects, presenting together, or communicate regularly to continue their support and development. The empowering nature of the model lasts long after the experience has finished.

As may be clear from the previous paragraph, the V-PLC setup is highly conducive to improving self-efficacy. There are multiple examples in the data of interactions that can be classified as vicarious, verbal persuasion, mastery experiences, and having a positive impact on affective state.

Teacher learning should occur throughout their professional life (Feiman-Nemser, 2001). In the case of the elementary fellows in this study, there is an added urgency for this learning. As alluded to in the introduction, NGSS reforms require excellence in science teaching at the elementary level. This requires professional skill in teaching, being able to plan lessons that support students developing deeper understandings of concepts and responding to students’ questions and misconceptions (Reiser, 2013). In many elementary classrooms, teachers are ill prepared or unable to take time to prepare science lessons that support the development of deeper understandings in science. The experiences of elementary fellows in the V-PLC model indicate social collaboration with
secondary peers allows for a focus on shared practices and common understandings. This fits well into the notion of knowledge of practice as described by Cochran-Smith and Lytle (1999). Knowledge of practice is a widely recognized mode of effective teacher learning and is central to what elementary fellows experience in the V-PLC model.

In a traditional view of staff development, “workshops and conferences conducted outside the school count, but authentic opportunities to learn from and with colleagues inside the school do not” (Lieberman, 1995, p. 591). The experience of participating in a V-PLC runs counter to this. The use of video permitted the elementary fellows to be observers in the rooms of their V-PLC peers, while the V-PLC debriefs and reflections provide authentic opportunities for elementary fellows to engage in discussion about shared practices. At the same time colleagues are socially constructing or developing new knowledge about what works, why, and how this impacts student success.

**Limitations and Conclusion**

In the data presented in each of the three studies, one sees much evidence of elementary fellows working hard to generate new knowledge, learn and get better at how to engage and support their students in the learning of science. In the literature, researchers often report that elementary teachers repeatedly fail to take time to engage students in important science ideas (Abrahams & Reiss, 2012; Mercer, Wegerif, & Dawes, 1999; Roth et al., 2006). This seems contrary to the findings in this study, in which the 28 elementary fellows all demonstrate a keen desire to improve their science
teaching in the data and there are plenty of discussions and reflections that indicate elementary fellows are concerned with engaging students in high quality science.

Indeed, in the literature there is plenty of concern around the kind of science teaching that occurs in elementary school classrooms. For example, it is reported that questioning and discourse in elementary science classroom is generally right answer focused (Newton, Driver, & Osborne, 1999; Reinsvold & Cochran, 2012; Roth, 2014). Yet, in this study, elementary fellows and their upper level peers engaged in video observations of questioning in classrooms, provided supportive and constructive feedback and reflected on how to best implement high quality questioning in their science teaching. One fellow even reflected about the best way to support students understanding of what a ‘good question’ is.

When one examines the data, only three out of 28 elementary fellows across the three cohorts do not feature in any of the 527 coded units of data. These individuals are Bella, Arianna and Kylie. It is interesting that their voices did not stand out in the data; however, both Bella and Arianna are actively involved in engaging their students and using other funding sources that are available to the fellows once they completed their two-year cycle. These two elementary fellows are also actively involved in the community of fellows that the university-based leadership team regularly engages with. Perhaps their experiences were not positive, or they did not feel completely comfortable sharing their success or failures in the various documents they were filling out. That being said, their post fellowship feedback and engagement has been very positive, so there may be a contextual reason, as their voices did not stand out during my analysis.
The one remaining elementary fellow whose voice did not emerge from my coding analysis is Kylie. Kylie was an interesting case in this fellowship. On one hand she seemed to be very engaged and openly interested with the leadership team, yet on the other we received reports from various sources that behind closed doors she regularly voiced her displeasure with the requirements of the program. Additionally, when one reads through many of her reflection journals, it seems she did believe she would gain something from the experience, and she often stated how her experience meant that she was really only providing support to her less experienced colleagues. The irony of the situation is that when compared across the 28 elementary fellows, Kylie’s experience was below the average experience which stands at 15.7 years.

In general, it seems that the science education community has a dim view about the future for science education at the elementary level. In her chapter on elementary science education, Roth (2014) states:

At best, we can hope that elementary teachers’ desire to make science interesting for students will engage and maintain student interest and identity in science. But this is not enough to meet society’s needs for science literacy. (p. 363)

Yet, I suggest that the data and findings in this study do not agree with the consensus of inevitability that seems overly prevalent in the community. I believe that the three studies provide much for our community to be encouraged about. The elementary fellows engaged in the program were highly motivated to be successful and took full advantage of the opportunity to socially engage, create and build upon a shared knowledge of practice with their upper level peers. There is evidence from almost all of the elementary teachers (25 of 28) that shows they learned a tremendous amount about supporting student success in science, but that they also provided middle and high school
teachers with important skills for supporting the development of students’ literacy skills. Moreover, evidence shows that the structure of V-PLCs creates interactions and experiences that are tailored to improving the self-efficacy of elementary science teachers.

Lastly, the science teaching practices that the elementary fellows identified and worked on improving and developing more knowledge about with their upper level peers all aligned very nicely as supporting practices for the Windschitl et al., (2012) three core discursive practices. The effort and enthusiasm of these elementary teachers is exciting to observe and the work that they engaged and excelled in along with their self-reported feelings of support and confidence to teach better science lessons indicates that the V-PLC model could be a very useful tool for professional development of currently practicing elementary science teachers. This is particularly so in states or districts where the NGSS has been adapted, as the vertical nature of the V-PLC permits elementary teachers to see how the science they teach in their classrooms will be built upon in the learning progressions of NGSS as student progress through their school careers.

Elementary science teachers were given the opportunity to build professional relationships, develop understandings of effective science teaching practices and better understand the role of science teaching in the K-12 spectrum.

While there is much to be excited about and the V-PLC model has shown in the data to be effective for elementary teacher science teaching practice development, there are limitations to the study. Although the elementary fellows in this study are located in five different school districts, they are from one geographical area in the northeastern United States and are not representative of elementary teachers in other parts of the
country. However, the fellowship has expanded to cover seven states, so future research should definitely examine the impact of V-PLCs on elementary fellows in these other states.

Other limitations with the study include the observations of the fellows. For a stronger case to be made for V-PLC effectiveness on teacher practice, fellows will need to be followed into their classrooms before, during and after the program and careful observations conducted to examine their science teaching practices and the impact of these on their students. For example, there is evidence in the literature that even with strong support, teachers may struggle to implement strategies that permit more control and regulation of learning by the students (Lewis et al., 2015). In these three studies, there is plenty of data that shows discussion and reflection about incorporating innovative pedagogical strategies and skills to support student learning, yet it is not known how these good intentions may translate into the classroom. There is some discussion about implementing this kind of analysis in the larger fellowship as a whole, which would be very useful and interesting research.

Finally, the study is also limited by the sustainability and longevity issue. While fellows participating in the debriefs clearly gain significantly from their experiences, this study does not attempt to follow fellows over a longer period or account for sustainability of their practice.
Future Research

While there are many facets that need to be addressed to align the science education in elementary school to NGSS, one model that shows significant promise for supporting elementary science teachers develop and sustain high quality science teaching practices is the V-PLC model. V-PLCs provide a unique supporting structure that addresses many essential components for effective teacher development and permits elementary school teachers to step outside of their normal context and grow and develop as practitioners with their students’ needs in clear focus. Many of the examples I found in the data did not fit the practice or student success narratives the elementary fellows shared.

One question that still needs to be investigated is, what does this model look like in other contexts? Depending on funding, this may be my next project, as the fellowship expands into seven states, and I potentially will be able to work alongside the seven sites to collect and analyze data examining this question. Exciting areas for research would include case studies of V-PLCs across different contexts, and how do different variables, such as context and state and local demands affect the outcomes of the V-PLCs?

Another area that needs more research is what does this look like in the actual classrooms of fellows over time, and away from the official structure of the program. To follow up from a study examining practices of fellow over time, one may also consider observing how or if a fellow is able to act as a seed for their school or district and build a community of practice where they share their professional capital with other teachers.

One idea might be to focus a study on the improving the effectiveness of each
V-PLC debrief. Perhaps if the university leadership team conducted regular reviews of
debriefs and met with the V-PLC after each time debrief, they could provide the
structured guidance to V-PLC participants. The structured guidance could help guide
PLCs who might struggle to identify practices the support the high-quality core practices,
provide support to latter adopters of the change who may need more support to enact
some of the practices, and give university faculty the opportunity to build and develop a
partnership in which they become mutually trusted and valued member of the
community.

**A Message for the Science Education Community**

A failure to provide elementary students with a high-quality science education
experience means that students will enter middle and high school with huge gaps in their
science knowledge, and a distinct inability to think scientifically about the world around
them. The community has done much to create the research that ultimately led to the
creation and implementation of NGSS or NGSS based standards, which are predicated on
a system of science education that is not currently in place in the majority of elementary
schools in the United States.

One concern in the literature might be that there seems to be a sense of negativity
around science in elementary school. Researchers classify the problem as the gap
between research and practice (Roth, 2014; Windschitl & Calabrese Barton, 2016) and
are quick to point out that what we know about how children learn science best is light
years ahead of the teaching practices in elementary school. They also identify correctly, I
believe, that we need to look at developing a set of practices that incorporates improving student learning and broadens student participation (Windschitl & Calabrese Barton, 2016). The big issue, is that the research has already informed a national set of science standards, the NGSS, and many states have adopted these (17 at the time of writing). This issue, therefore, is that policy makers and district/school administrators are already making decisions about the new standards documents, and the practitioners for the most part have very little idea about what these standards entail, or what sort of shift in instruction they need to make in order to begin implementing instruction that is more in line with the vision of NGSS and the Framework.

In the literature, researchers have conducted few studies that look to support current elementary teachers to incorporate the kind of science the NGSS calls for. There are no published studies that could be found that investigate supporting elementary science teachers through vertical aligned learning communities or studies that investigate what elementary teachers know about instruction that is aligned with the ‘ambitious teaching’ referenced by Stroupe (2014); Windschitl and Calabrese Barton (2016) and Windschitl et al., (2012). Elementary science teachers need a model for professional development that offers them the opportunity to interact with peer practitioners and develop a supportive community of practice that can grow in knowledge about how best to support student learning in science. They need such a model now.

This study presents a fresh perspective on the desire and ability of elementary teachers to engage with and build their skills and practices in the teaching of science. As science educators, we need to ask what we are going to do to support elementary teachers in learning how to implement and support high impact science practices and effective
ways to support elementary student success in science. This cannot wait. Failure to take action quickly, is this equivalent to building a skyscraper without a foundation or a stone arch without a keystone, the NGSS will be doomed to catastrophic failure. Elementary science is the foundation for students’ science learning pathway in the United States and elementary teachers are a critical part in ensuring this foundation. In this study, the V-PLC model has been shown to support elementary teachers in socially constructing knowledge of high quality science teaching practices which provide a solid base for aligning science instruction at the elementary level to NGSS envisioned science. Furthermore, seeing their place in the K-12 journey and understanding how important their role is for motivating elementary teachers to work with their peers to improve their science teaching. V-PLCs can function as a keystone for elementary science education. Building a theory around core practices is great, but will we, the science education community act in enough time to make a meaningful impact on the elementary science crisis?
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Association for the Advancement of Science. (1989). *Science for all Americans.* Washington, DC.


Walton, E., Nel, N., Muller, H., & Lebeloane, O. (2014). ‘You can train us until we are blue in our faces, we are still going to struggle’: Teacher professional learning in a full-service school. *Education as Change, 18*(2), 319-333.


*Journal of Teacher Education, 63*(5), 376-382.
Appendix A

Fellow PLC Debrief Protocol

Prior to Debrief Meeting

- Fellow being observed
  - Fellow records the lesson that he or she had signed up to do and the lesson matches what you filled out on the “Form 1: Pre-Observation Form”. The “Pre-Observation Form” was already distributed and discussed at the previous debrief meeting; “Pre-Observation form” is also posted onto group’s V-PLC page.
  - Fellow selects representative body of student work from the lesson that was videotaped and will bring to the meeting. Copies of this work should be brought to the meeting and put into the group binder that will be submitted in January.
  - Fellow checks recording and saves it to hard drive.
  - Fellow uploads video. (We will show you how to do this.). DO NOT DELETE VIDEOS from hard drive at this time.

- Fellows observing
  - Read the pre-observation information (Form 1).
  - Review the entire video with close attention paid to looking for how the course of study is demonstrated in this lesson and student learning. It is your responsibility to make sure you receive the invite to the video.
  - Take notes and write down any questions you may have about the lesson on “Form 2: Video Observation Note Taking Sheet”.
  - Bring “Form 2” notes to debriefing meeting.

- Facilitator
  - Checks in with Fellow being observed if pre-observation form or video has not been received by agreed upon time.
  - Completes everything the “Fellows Observing” also needs to do.
  - Brings video camera to meeting to record meeting.
  - Brings a watch so that he or she can keep time during the meeting.

- Fellow being observed next
  - Completes “Form 1: V-PLC Pre Observation Form” and posts to Dropbox prior to meeting
  - Comes prepared to the meeting to lead a five-minute pre-observation dialogue on the lesson they will be videotaping
  - Brings copies of Form 1 to debriefing meeting
## Debrief Meeting

<table>
<thead>
<tr>
<th>Approx. Time</th>
<th>Step</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior to meeting</td>
<td>Facilitator sets up video camera to tape the meeting</td>
</tr>
<tr>
<td>1 Min</td>
<td>Facilitator reviews norms of the group; begins to keep time to make sure the conversation keeps moving according to the schedule.</td>
</tr>
<tr>
<td>5 Min</td>
<td>Fellow being observed sets context for lesson and describes lesson being taught</td>
</tr>
<tr>
<td></td>
<td>• States the age level and grade of students</td>
</tr>
<tr>
<td></td>
<td>• States what part of the day this lesson took place</td>
</tr>
<tr>
<td></td>
<td>• Explains any unusual or important facts that occurred that day that may have impacted the lesson</td>
</tr>
<tr>
<td></td>
<td>• Explains what the lesson that was videotaped was on</td>
</tr>
<tr>
<td></td>
<td>• Explains what the lessons before and after this particular lesson was on</td>
</tr>
<tr>
<td></td>
<td>• Explains how this lesson connects with the course of study</td>
</tr>
<tr>
<td>1 Min</td>
<td>Fellow being observed restates the questions from the pre-observation form that the Fellow has about his or her lesson</td>
</tr>
<tr>
<td>4 Min</td>
<td>Fellows fill out “V-PLC Feedback Sheet” (Form 3) based on observations that were recorded on “V-PLC Observation Notes” (Form 2) (Or do this ahead of time.)</td>
</tr>
<tr>
<td>10-15 Min</td>
<td>Warm and cool feedback is given by Fellows (including Facilitator). Facilitator makes sure that the conversation is focused on the course of study topic and student learning. Facilitator makes sure that the conversation keeps moving. Facilitator makes sure norms are adhered to. Facilitator makes sure this part of the conversation is beginning to wrap up around 10 minutes into this part of the meeting by asking if there is anything else anyone would like to share. During this time, the Fellow being observed is taking notes on the “Demonstration Teacher Feedback Gathering Sheet” (Form 4) but is not part of the active conversation (i.e. does not talk but just writes during this time).</td>
</tr>
</tbody>
</table>

### Guidelines for Warm Feedback:
- a. Don’t criticize or compliment
- b. Name what is effective
- c. Let the fellow know what is working
- d. Point out where, in the lesson, the fellow successfully met their goal and provide evidence supporting it.

### Guidelines for Cool Feedback:
- a. Ask the fellow to consider “What if…” or “I wonder what would happen if…”
- b. Rather than telling the fellow what needs more thought or consideration, ask them questions about the lesson.
<table>
<thead>
<tr>
<th></th>
<th>c. Provide statements or questions that tune the fellow into areas of disconnects, gaps, dilemmas, or other areas of “weakness” in the lesson plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Min</td>
<td>Fellows can ask the Fellow being observed any clarifying questions about the lesson and the Fellow being observed may answer during this time. Facilitator makes sure that this does not go over 5 minutes.</td>
</tr>
<tr>
<td>10-15 Min</td>
<td>Fellows, including Facilitator and Fellow being observed, EVERYONE connect what they observed to the research article that is guiding the course of study</td>
</tr>
<tr>
<td></td>
<td>- Did the lesson implement the research from the course of study?</td>
</tr>
<tr>
<td></td>
<td>- How does the research help the group to answer the pre-observation questions the Fellow being observed posed?</td>
</tr>
<tr>
<td></td>
<td>- How can the research inform this lesson if it was to be repeated again?</td>
</tr>
<tr>
<td>30 Min</td>
<td>Fellows (including Facilitator and Fellow being observed) EVERYONE look at the student work</td>
</tr>
<tr>
<td></td>
<td>- How does the student work connect to the course of study and the lesson?</td>
</tr>
<tr>
<td></td>
<td>- How does the student work demonstrate student learning?</td>
</tr>
<tr>
<td></td>
<td>- As an observer, what does the student work tell you?</td>
</tr>
<tr>
<td>5 Min</td>
<td>Everyone, including facilitator, shares what they learned from this, with the Fellow being observed going last</td>
</tr>
<tr>
<td>5 Min</td>
<td>Pre-Observation Dialogue for Fellow who will be observed (videotaped) next</td>
</tr>
</tbody>
</table>

**Post Meeting**

- Fellow that was observed
  - Reads “Form 3: V-PLC Observation Feedback” from everyone
  - Completes “Form 6: Demonstration Teacher Reflection”
  - Sends everything to facilitator (or if handwritten, give it to him/her at next meeting)
- Fellows that did the observing
  - Completes “Form 5: Meeting Reflection”.
- Facilitator
  - Completes same post-observation form as other Fellows observing.
  - Makes sure that Form 1, Form 5, and Form 6 are put into the V-PLC binder.
  - Uploads the video of the debrief meeting. DO NOT DELETE THE VIDEO FROM YOUR HARD DRIVE at this time.
Appendix B

Fellow Monthly Reflection Prompts

September

1. What is your experience with PD? Has PD ever provided you with positive growth in your practice? What negative experiences have you had?

2. What are your thoughts about the CTS model? Have you used this in your own practice? How could you use this tool for your own growth?

3. How well developed do you feel your content and conceptual knowledge is?

4. How much do you know about how students learn and think about science and when did you acquire this knowledge?

5. What sort of reflective practice do you have experience with? How has this helped you to develop your practice? Provide some examples.

October

1. How does the Larrivee article fit your personal teaching philosophy?

2. How can the reflective practitioner described by Larrivee lead other teachers within their professional community?

3. How do you approach/view the connection between science and literacy in your classroom? Does Bybee Chapter 4 make you rethink any aspect of this? How does the NGSS address this connection?

4. How do you approach the alignment of curriculum, instruction and assessment in your practice?? Why do you have this approach?

5. What are your feelings/thoughts about NGSS? What more do you need/want to know?
November

Reading - Chapters 9 and 10 in the Bybee

Reflection prompts:

Please use the 3-2-1 format for reflecting on the readings this month.

3 - things or areas that are becoming clearer/became clearer to you from the readings

2 - connections that you made between the readings and your prior experiences/knowledge

1 - question/area that is unanswered or requires further clarification

December

No Reflection Prompt

January

1. In what ways did your V-CCLS group work support your professional growth as an educator? Please provide as much detail as you can.

2. What did you learn about student scientific knowledge while working in your V-CCLS group? What about teacher scientific knowledge?

3. Describe how/if the NGSS informed or helped you during lesson planning/V-CCLS group debriefs/discussions etc?

4. Did you feel that V-CCLS groupings are a good way to develop your knowledge of NGSS? Why? Why not?

5. Would you consider using a similar vertical grouping for professional development in your school district? Why? Why not?
6. Explain how this semester’s experience did/did not help you feel more capable to teach science.

February

1) In what ways does your science teaching accommodate, connect or share commonalities with the science and engineering practices described in NGSS? Describe.

2) As a science teacher how do you feel about NGSS science and engineering practices? What are your concerns, hopes, uncertainties?

3) How did your experiences in V-CCLS groups connect with science and engineering practices?

4) What are your hopes and goals for the H-CCLS group experience? Are there specific aspects of science and engineering practices that you would like to address within your new groups?

March

1) How has your understanding of and ability to impact student learning grown since you have joined Wipro SEF? How has interacting with your V-CCLS and H-CCLS peers helped you in this? Please describe in as much detail as you can.

The next few reflection prompts will start you thinking about issues or questions that you may focus on next year during your GPS project.

2) What are some issues or questions you would like to explore in your classroom/school setting?

3) How could you go about investigating the aforementioned issue/s in your classroom/school?
4) What data would you need to collect?

5) How would you analyze the data you collect? How would this help you effect a change in the issue you chose to address?

April

No Reflection Prompt
## Appendix C

### Fellow PLC Debrief Forms 1-6

<table>
<thead>
<tr>
<th>V-PLC</th>
<th>Form 1</th>
<th>Pre-Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demonstration Teacher:</td>
<td>Date:</td>
<td></td>
</tr>
<tr>
<td>Class:</td>
<td>Age(s) of Students:</td>
<td></td>
</tr>
<tr>
<td>Grade Level:</td>
<td>Topic:</td>
<td></td>
</tr>
<tr>
<td>Time Lesson Started:</td>
<td>Lesson Objective(s):</td>
<td></td>
</tr>
<tr>
<td>Time Lesson Finished:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Where does this lesson fit within the unit that you are teaching?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>What would you like the observers to focus on during their observations?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Questions for Me to Ponder as the Demonstration Teacher:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How do you think this lesson will tie to the Course of Study?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>What student work do you anticipate that you will collect?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How do you plan to determine if your objectives have been met?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are there any unusual circumstances or special conditions that the observers should be aware of?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Fellows use this form to capture their thoughts and observations while watching the Demonstration Teacher’s video. This form is not shared but is used to complete Form 3.

<table>
<thead>
<tr>
<th>Demonstration Teacher:</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class:</td>
<td>Age(s) of Students:</td>
</tr>
<tr>
<td>Grade Level:</td>
<td>Topic:</td>
</tr>
</tbody>
</table>

Capture your thoughts regarding the Demonstration Teacher’s areas of focus, and in relation to the Course of Study and Science/Engineering Topic.
<table>
<thead>
<tr>
<th>V-PLC</th>
<th>Form 3</th>
<th>Observation Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demonstration Teacher:</td>
<td>Date</td>
<td></td>
</tr>
<tr>
<td>Class:</td>
<td>Topic:</td>
<td></td>
</tr>
<tr>
<td>Focus of the Observation:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warm Feedback: What went well…</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cool Feedback: Potential Areas to Explore…</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Questions for the Demonstration Teacher to Ponder:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suggestions on how research could strengthen this lesson:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observer:</td>
<td></td>
<td></td>
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</tbody>
</table>
V-PLC Form 4 Demonstration Teacher Feedback Gathering Sheet

<table>
<thead>
<tr>
<th>Demonstration Teacher:</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class:</td>
<td>Topic:</td>
</tr>
<tr>
<td>Focus of the Observation:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Warm Feedback</th>
<th>Cool Feedback</th>
</tr>
</thead>
</table>

Questions for Me to Ponder:

Ideas that I am getting on what to do based on the feedback:
All members of the group, including the facilitator, reflect on each aspect of the debrief meeting. Please use your notes from Forms 2, 3 and the feedback you heard from the other observers and the Demonstration Teacher to complete this form.

<table>
<thead>
<tr>
<th>Name</th>
<th>Date</th>
</tr>
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<tbody>
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</tbody>
</table>

Reflection: As a result of this meeting, I…

<table>
<thead>
<tr>
<th>What was most helpful?</th>
</tr>
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<td></td>
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</table>

<table>
<thead>
<tr>
<th>I could see how the lesson related to the research by…</th>
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</table>

<table>
<thead>
<tr>
<th>I could see how the group looking at student work enhanced by learning by…</th>
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<table>
<thead>
<tr>
<th>A suggestion for our next meeting…</th>
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<tbody>
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</table>

<table>
<thead>
<tr>
<th>Anything else?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>
The Demonstration Teacher takes a few moments to reflect on the feedback and process.

<table>
<thead>
<tr>
<th>Demonstration Teacher:</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>My Initial Reflections:</td>
<td></td>
</tr>
</tbody>
</table>

**One or two areas that I would like to explore**

<table>
<thead>
<tr>
<th>Area to Explore:</th>
<th>Area to Explore:</th>
</tr>
</thead>
<tbody>
<tr>
<td>What I will Attempt:</td>
<td>What I will attempt:</td>
</tr>
<tr>
<td>The support I will Need:</td>
<td>The Support I will need:</td>
</tr>
<tr>
<td>How will I know I am successful?</td>
<td>How will I know I am successful?</td>
</tr>
</tbody>
</table>