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Learning About Teaching Science: Improving Teachers' Practice Through Collaborative Professional Learning

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Abstract

This single, descriptive qualitative case study provides a snapshot of elementary teachers and their school principal's multiple and competing views about personal and contextual factors affecting teacher engagement in collaborative professional learning (CPL) related to science education within the school environment. This study was viewed through the lens of Situated Learning Theory primarily by Lave and Wenger (1991) because viewing knowledge as situated has implications for understanding teacher learning and the design of instructional activities.

Data were collected from three female elementary teachers and their school principal in Ontario for a period of six months. The data included: five principal interviews; two teacher focus groups; three surveys (Science Teaching Efficacy Beliefs Instrument, Science Teachers' Pedagogical Discontentment scale, Beliefs about Reform Science Teaching and Learning); two questionnaires (demographics questionnaire, Professional Development Continuum Rubric) and; monthly professional development logs. The process of thematic coding was employed to analyze the data, and the findings were written with thick descriptions based on the narratives from the participants and descriptive data.

Three interpretive insights and implications into the synthesis of the findings included: (a) the lack of emphasis on science in Ontario's elementary education, (b) the limited time available for CPL about science, and (c) the limited number of teaching partners to collaborate about science. The interconnectedness of the three concepts highlights the multiple and complex domains that influence teacher engagement in collaborative professional learning related to elementary science education in Ontario, Canada.

The overarching implication put forward in this research is the provision of ongoing professional learning with in-situ instructional science coaches working alongside the teachers to further develop their science teaching strategies related to inquiry-based approaches. To implement such concept, it is suggested that science is included in the School Effectiveness Framework so that when individual schools include science in their School Improvement Plan. Secondly, time for CPL needs to be included in teachers' Collective Agreement. The benefits of these changes may include more

teachers across the school engaging in CPL related to inquiry-based science, and expanding the network of teachers who collaborate with one another regarding science within the school setting.

Keywords: Collaborative Professional Learning (CPL); Elementary Science Education; Elementary Science Teachers; Elementary School Principal; Inquiry Science Learning; Case Study; Situated Learning Theory; Instructional Science Coaching

Dedication

To my guardian angel who provided me with the strength, perseverance and passion to follow my heart, dedicate myself, and to always work hard to acheive a dream. With his countless life lessons, unconditional love and belief in me, I was able to complete this journey – Thomas Russo.

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I am grateful to the school principal of this study. Not only did he provide me with access to incredible teachers, he motivated me to keep working hard and dig deeper into the research topic. It was a pleasure to interact with the school principal and the teachers as it made data collection enjoyable and enlightening.

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CHAPTER I: THE RESEARCH PROBLEM

Student achievement is directly related to the quality of teaching students receive (Hattie, 2008; Katz & Dack, 2013). Nye and colleagues reported that seven to 21 percent of student variance in achievement gains has been associated with variations in teacher quality (Nye, Konstantopoulos, & Hedges, 2004). Also, Hattie ranked 138 factors that influence student achievement: seven of the top 10 factors were directly related to teacher factors such as the quality of their instruction, clarity, and feedback (Hattie, 2008). Specifically related to science education, Jones and Leagon (2014) said: “perhaps the single most important factor in the quality of science education is the teacher” (p. 830). Considering that student understanding for science education, in part, begins with their teachers (Chen, Morris, & Mansour, 2015), “all students need teachers who can provide meaningful, authentic, and rigorous opportunities to learn science” (Lewis, Baker, & Holding, 2015, p. 897).

Discussing the influence of teaching quality on student academic achievement regarding science education is necessary because it is well documented by scholars and practitioners that there is a current “lack of sophistication that students have with regard to their basic scientific literacy” (Chen et al., 2015, p. 371). Given this, there is a need to improve the quality of elementary science education by developing teacher knowledge and instructional strategies. One means to help teachers develop their science knowledge and instructional strategies is by encouraging and supporting teachers to engage actively in ongoing, collaborative professional learning. The dilemma is that change to teachers’ science practice as a result of their engagement in collaborative professional learning related to science has been a small and slow (Roth, 2014).

This research focuses on reform-based collaborative professional learning related to elementary science education that is: (a) ongoing throughout teacher’s regular routine, (b) embedded in the school environment and engages multiple teachers in collaborative learning, and (c) relevant to teachers learning and teaching needs.

Research Purpose and Goals

The purpose of this study is to illuminate elementary teachers and their school principals’ multiple and competing views about personal and contextual factors affecting teacher engagement in collaborative professional learning related to science education

within the school environment. By placing teachers and their administrators at the centre of this research, they are central to understanding the nature of collaborative professional learning within the elementary school and are key to better understand affordances and constraints associated with this enactment. To examine the complex relationships embedded within collaborative professional learning, the goals of this research are the following:

- To capture the daily experience of teacher engagement in collaborative professional learning related to science education.
- To expose the current support and challenges that elementary teachers face in a suburban school in Southwestern Ontario when attempting to learn about science, and to learn about how to teach science through engaging in collaborative professional learning.
- To highlight the opinions of elementary teachers and their principal so they can work collaboratively to ensure that teacher needs are met when learning about science and how to teach science.
- To clearly and simply outline factors influencing teacher engagement in collaborative professional learning related to science education so that the findings are well communicated and relevant to other educational researchers, teacher educators, and the local school board.

Research Questions

This study was guided by the following research questions about collaborative professional learning and elementary science education:

1. What are the perceptions of teachers and their school principal regarding collaborative professional learning related to science as a vehicle for their professional growth related to science?
2. How do teachers perceive that participating in collaborative professional learning transforms their students' science learning?
3. What does teacher participation in the practice of collaborative professional learning related to science look like?

4. What initiatives has the school principal taken to engage teachers in collaborative professional learning for science?
5. What factors contribute to, or hinder, teacher collaborative professional learning related to science?

Contributions to the Field of Science Education

Ongoing professional learning has been researched in depth from several perspectives (Goldsmith, Doerr, & Lewis, 2014), and much is known about how to design effective, ongoing professional learning for teachers that extends beyond traditional modes of teacher learning (Timperley, Wilson, Barrar, & Fung, 2007). Research has shown independent relationships between professional learning and teaching practice (Kang, Cha, & Ha, 2013), teacher knowledge (Penuel, Fishman, Yamaguchi, & Gallagher, 2007), and increased self-efficacy (Palmer, 2011). But only a few empirical studies have researched the relationship between professional learning, teacher knowledge, attitudes, and teaching practice (Banilower, Heck, & Weiss, 2007; Garet, Porter, Desimone, Birman, & Yoon, 2001; Heck, Banilower, Weiss, & Rosenberg, 2008). Moreover, fewer studies have included context variables such as principal support and curriculum materials (Banilower et al., 2007; Heck et al., 2008) and even less research has focused on these factors within the domain of science (Heller, Daehler, Wong, Shinohara, & Miratrix, 2012). As a result, Loughran (2014) acknowledged this gap in the research literature and stated: “now is the time for science education research and practice to better demonstrate, articulate, and celebrate teachers’ professional knowledge of practice and to highlight the place of science teacher learning in progressing the profession in positive and productive ways” (p. 825).

The research literature that currently exists for teacher professional learning related to science education will be strengthened by better understanding the affordances and constraints associated with teacher engagement in well-tailored professional learning programs (Rotherham, Mikuta, & Freeland, 2008). Crawford (2014) also agreed with Rotherham and colleagues and added that “it would be helpful to reexamine the issues science teachers themselves identify as being problematic” (p. 536). Capps and colleagues (Capps, Crawford, & Constan, 2012) also expressed that more research is necessary on professional learning programs, inquiry, and teacher knowledge, practice,

and beliefs regarding science education. In the *Handbook of Research on Science Education, Volume II*, Roth (2014) expressed that too few studies exist that investigate the supports and challenges that teachers face for elementary science teaching.

It is understood that internal elements (e.g., the context, teacher beliefs, school culture, and teacher confidence, and attitude) and external elements (e.g, policy issues, leadership resources, student population) need to be taken into consideration when addressing the instructional science practices of teachers (Hayes & Trexler, 2015) and implementing effective collaborative professional learning. But first, it is important to understand the daily routine and needs of elementary teachers teaching science considering that they are responsible for teaching multiple subject areas including science, along with managing multiple other daily activities that may or may not be in their control. Roth (2014) explains that one means to help improve science teaching is by identifying “high-leverage science teaching practices” (p. 365). The idea is that teachers would learn only a few core teaching strategies that could be applied in their teaching practice. Then they would build on these strategies by slowly adding a few more strategies. Over time, this could transform their science teaching. Although I agree that this strategy may be beneficial to improve science teaching, questions that must first be addressed include: when, where, and how will this learning take place? To help address these critical questions and to create a change to the way teachers learn about science and teach science, we must first understand the perceptions of teachers and their administrators about science learning, and when, where, and how they believe it is possible for this learning to take place considering that teachers are at the front line of teaching science.

The qualitative, single case study design helped to provide an in-depth and holistic understanding of teacher engagement in collaborative professional learning in the subject area of elementary science. The design of the study also provided an approach to shed light on when, where, and how teachers and administrators believe it is possible for this learning to take place by considering the daily routine of teachers, and considering the responsibilities that the administrator holds over an extended period of time. Broadly, the research methodology included: (a) surveys to illuminate the participants opinion about the level of collaborative professional learning occurring at their school, teacher

epistemological beliefs, pedagogical discontentment and self-efficacy, (b) monthly logs of teacher engagement in collaborative professional learning in real time, and (c) focus groups with the teachers and interviews with their school principal that focused on the affordances and constraints associated with teacher engagement in collaborative professional learning related to science education. The findings of this study can help to: (a) tailor ongoing collaborative professional learning within a school setting by understanding and adapting to contextual factors to support science teacher engagement in collaborative professional learning and their science learning and teaching; (b) bridge the gap between theory-driven academic endeavors about the process of how teacher science learning occurs via collaborative professional learning, and current practice-oriented approaches; and (c) open the lines of communication between educational science researchers, school administrators, and teachers alike to help align goals and improve efforts to strive for effective participation in collaborative professional learning to improve Ontario's science education.

Researcher's Perspective

Because of the case study approach, I was the primary research instrument of data collection, data analysis, and interpretation (Denzin & Lincoln, 2005). Merriam (1998) explained that the philosophical orientation of the researcher is a fundamental consideration to the research. As such, the epistemological position of the researcher needs to be revealed to understand the possibility of bias given the final product of the research is an interpretation of the participants views filtered through the views perspective of the researcher (Merriam, 1998). Therefore, to gain trustworthiness of the research findings, it is important to disclose my biases and to understand how my viewpoint toward teaching and learning science might have an effect on my research.

My philosophical roots draw upon social constructivism to explain my worldview with regards to learning elementary level science. I believe that scientific facts exist on one hand, and on the other, is the subjectivity of developing those understandings. Therefore, each individual develops their internalized understandings (through dialogue and over the course of ongoing activity situated within an environment) of externalized realities. I feel that best practices in science teaching allow for students to negotiate meaning through experiences with science investigations in a social setting. The learners

need to learn from mistakes and repeat investigations by modifying variables to understand the scientific concept. I hold this position based on my educational background and teaching experience.

Throughout elementary and high school, I loved studying science – I received the top grades and felt accomplished. Then I went to university and earned an Honors Bachelor's degree in Science. Throughout my university studies, I kept waiting to learn about how my knowledge could be applied to real life situations. However, by the end of my bachelor's degree, I was tired of science – I was tired of memorizing facts and only studying to ensure I performed well on exams for the sake of being accepted into a graduate program. After earning my Master's of Science, I taught English abroad to elementary aged students. Because of my strong science background, I was primarily teaching science. My primary focus was to have my students understand how the science concepts could be applied to their daily lives. However, my goal clashed with other teachers and administrators who wanted me to teach using teacher-centered pedagogy that was not focused on student learning, rather the grades on standardized tests. As such, my personal background in science may have affected how I view teachers teaching science to elementary-aged students. These experiences may have helped and hindered my research because they added sensitivity to the context of teaching, yet thoughtful skepticism. I appreciated how teachers are bound by their personal background and skill set, political influences, curriculum, and other unexpected occurrences happening within the multi-dimensional, dynamic school environment that can deter research suggestions from being put into practice.

Because of my background, I do not claim to be an insider or an outsider per se. I am not solely an insider because I am not a member of the Ontario Certified Teachers community working as an elementary school teacher. Thus, I am not conducting research within a population of which I am also a member (Kanuha, 2000) who shares an identity, language, and experiential base with the study participants (Asselin, 2003). Although I am not an outsider to the experience of working as an elementary teacher, I cannot directly relate to the experience of teachers within the Canadian elementary school context. I relate to the experience of being an elementary school teacher who educates students, takes part in professional development conferences and workshops, collaborated

with colleagues, and implements curriculum, for a greater more diverse student population. Additionally, my investment in the educational research body means I cannot be an outsider to the research study. As a result, my position lies between the polar opposite outsider-insider designations which provide me an understanding of the research study by being aware of the intricacy of teacher collaborative professional learning within the school. As Dwyer and Buckle (2009) explain, this case study research does not force me to remain as a true insider or outsider: I “occupy the space between, with the costs and benefits this status affords” (p. 61).

Organizational Overview of the Remaining Chapters

In the following chapter, Chapter II, I detail a review of the relevant literature consulted in this study. Three major domains are addressed in the review: (a) the current state of elementary science education and teachers’ classroom practice; (b) collaborative professional learning for science education; and (c) external and internal contextual factors influencing teacher engagement in collaborative professional learning for science education. More specifically, contextual factors include school and policy related factors from the Ontario Ministry of Education, school principal leadership, and teacher beliefs (epistemological beliefs, self-efficacy, and pedagogical discontentment).

In Chapter III, I explore the utility of a social constructivist theoretical lens – called Situated Learning – for understanding teacher engagement in collaborative professional learning related to science. I primarily use Lave and Wenger’s (1991) model of Situated Learning Theory as the lens to address the research findings.

Chapter IV is a discussion on the methodology and methods applied to this study. This research was a qualitative case study of three elementary teachers teaching science at a suburban public elementary school. Data was collected for six months and included: principal interviews, teacher focus groups, surveys, questionnaires, and professional development logs. The process of thematic coding was employed to analyze the data, and the findings were written with thick descriptions that are based on the narratives from the participants and descriptive data. Lastly, issues of trustworthiness are discussed.

Chapter V presents the findings from the research data collected. A total of three themes were established that influenced teacher engagement in collaborative professional learning related to science.

Chapter VI, the discussion, elutes to three interpretive insights and implications into the synthesis of the three findings highlighted in Chapter V. I discuss the interconnectedness the three concepts and help readers to recognize that the concepts represent multiple and complex overarching domains that greatly influence teacher engagement in collaborative professional learning related to elementary science education in Ontario, Canada.

Lastly, Chapter VII highlights the research implications and potential strategies to implementing the implications, limitations and future recommendations that arose from the research study.

CHAPTER II: LITERATURE REVIEW

This chapter provides an overview of the research literature regarding teacher engagement in collaborative professional learning and related constructs. While there is a large body of research regarding this phenomenon, this review highlights topics related to collaborative professional learning and influential contextual factors related to elementary science education. Specifically addressed are factors related to national and local policy, principal leadership and teachers beliefs (epistemological beliefs, self-efficacy, and pedagogical discontentment).

Section 1: The Current State of Elementary Science Education and Teachers Classroom Practice

The National Research Council (2012) describes the goal of science as, “the construction of theories that can provide explanatory accounts of features of the world” (p. 52). To meet this goal in elementary science education, “the effective classroom teacher designs and adapts instructional materials and orchestrates the classroom to support children in learning how to carry out scientific practices and in understanding the nature of scientific inquiry” (Crawford, 2014, p. 526). Rather than teachers transmitting scientific facts to the students through lecture style instruction or observation and description activities, they facilitate students to be engaged in developing conceptual understandings through investigations and reasoning with evidence-based explanations - a process called *inquiry* (Roth, 2014). The National Research Council (2012) defines eight stages that guide scientific reasoning using an inquiry approach for elementary science teaching:

1. Asking questions
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations
7. Engaging in an argument from evidence
8. Obtaining, evaluating, and communicating information

Science education reform is underlined by the premise that students design questions that lead to investigations wherein they explore the phenomena and address questions by

gathering evidence to help them build a strong knowledge base and to formulate explanations based on evidence to describe their experiences and their learning (Abell, Anderson & Chezem, 2000; Folsom, Hunt, Cavicchio, Schoenemann, & D'Amato, 2007; Gagnon & Abell, 2008; Zembal-Saul, 2009). Lewis et al. (2015) explained that teachers who use “scientific inquiry as a teaching paradigm provides students with more opportunities, not only to engage with scientific questions, make observations, and make meaning from their own experiences, but also to talk with each other and not just their teacher” (p. 902). Moreover, Bevins and Price (2016) said: “inquiry is currently the best way for students” to learn as it provides students with “ownership of their learning and allows them to actively navigate the routes to increased understanding, greater motivation, improved attitudes to scientific endeavor and growth in their self-esteem and their ability to handle new data in an increasingly complex world” (p. 19). However, the research literature highlights the “stark contrast” (Roth, 2014, p. 387) between current teaching practices in elementary school science and what can be done to help students understand science concepts and to consider themselves as “competent science learners” (Roth, 2014, p. 387). Crawford (2014) expressed that although inquiry teaching has been a longstanding buzzword in reform documents about science education, “today, inquiry in the science classroom is advocated and expected yet surprisingly rare and enigmatic” (p. 516). Crawford (2014) continued to acknowledge that it is challenging for elementary teachers to apply inquiry-based instruction: “these ways of teaching are sophisticated and challenging” - particularly when the skills are foreign to teachers, and they are not engaging in effective science learning activities to learn and teach the skills (p. 537).

The contrast between research on best practices for science learning and teaching, and what is typically implemented in elementary schools exists in part, because “science educators continue to debate the place of inquiry in the teaching of science” (Duschl, Schweingruber, & Shouse, 2007, p. 12) and teachers struggle with what inquiry teaching should look like and how it should be taught (Gillies & Nichols, 2015). Zhang, Parker, Koehler, and Eberhardt (2015) found that inquiry teaching was “one of the greatest challenges for most teachers” (p. 492) and their finding was consistent with other researchers (e.g., Crawford, 2007; Johnson, 2006; Wee, Shepardson, Fast, & Harbor, 2007). Consequently, in contrast to what the research says and policy asks for with

regards to teaching science with an investigation-orientation, the science practice and perspectives that teachers hold have remained essentially unchanged for over the last fifty years (Duschl & Osborne, 2002); therefore, changes at the school level have been slow (Roth, 2014). Traditional ideas about teacher-centered pedagogy and the objectives of science education have prevailed. Rather than thinking of science as a process of discovery, teachers tend to view and teach science as a set of disconnected facts to be learned from a textbook, lectures, and worksheets (Gray & Bryce, 2006). As a result, students are largely engaged in activities that involve passively listening and taking notes. Rarely do they engage in investigations, and if they do, they are likely verifying known results (Crawford, 2014). Alternatively, teachers may engage students in hands-on activities without making the connection between the activity and science applications or real-life situations (Roth, 2014). Overall, “although there are pockets of excellent elementary science teaching, the larger picture is grim” (Roth, 2014, p. 363).

The larger picture of elementary science education being grim is evident in Ontario, Canada. In 2007, the Ontario Ministry of Education released a revised curriculum for science and technology. It states that teachers are responsible for guiding students to learn critical and creative thinking skills through investigation, exploration, observation, and experimentation. The problem that Pedretti and Bellomo (2013) highlighted in their work with 24 elementary teachers in a large school district in Ontario is that the new science curricula has been a challenge for teachers to adopt. Research has shown that the challenges for teachers to adapt to the new curriculum standards for science education may stem from the fact that elementary teachers are trained as generalists in their formal teacher education training; they are not experts in science (Appleton, 2006). Therefore, for the most part, they lack comprehensive science content knowledge (e.g., Bleicher & Lindgren, 2005; McDonnough & Matkins, 2010) and pedagogy to teach reform-based science (e.g., Diaconu, Radigan, Suskavcevic, & Nichol, 2012; Penuel et al., 2007), have minimal training to teach inquiry-based science education (e.g., Kidman, 2012; van Aalderene-Smeets, van der Molen, & Asma, 2012), and regardless of available curriculum materials, Schneider, Krajcik, and Blumenfeld (2005) found that teachers lacked the ability to teach using an inquiry approach. Moreover, elementary teachers largely do not have the adequate pedagogical knowledge

to implement their inquiry-based method of instruction to students presenting challenges (Diaconu et al., 2012; Lee, Lewis, Adamson, Maerten-Rivera, & Secada, 2008; Smith & Southerland, 2007). As a consequence of inadequate content and instructional strategies, when teachers teach unfamiliar topics such as science, they are more likely to present questions prefaced by “what” and “how” rather than addressing questions that help students build conceptual understanding (Songer, Lee, & McDonald, 2003). Compared to elementary teachers with weaker content knowledge, teachers with strong content focus pose more questions, are more likely to have students consider alternative explanations, and propose more investigations (Alonzo, 2002). Additional reasons for why the larger picture of elementary science teaching is grim and teacher-oriented are: (a) engaging students in science inquiry means that teachers need to be comfortable with having unanticipated questions and ideas posed by their students. However, for decades, it has been known that elementary teachers often lack the confidence to teach science (e.g., Andersen, Dragsted, Evans, & Sørensen, 2004; Appleton, 2006; Northfield, 1998; Perkes, 1975; Riggs & Enochs, 1990); (b) teacher receptiveness to inquiry teaching depends on whether they foster the belief that this type of teaching is valuable, and whether they have a support system to help foster these beliefs (Crawford, 2014); and (c) science teaching is restricted by federal and local accountability demands in other subject areas. Therefore, developing new curricula and policy documents does not guarantee or promote teachers use of inquiry teaching in science (Crawford, 2014).

In addition, the results from the 2011 *Trends in International Mathematics and Science Study* (TIMSS) support the notion that the larger picture of elementary science education is grim in Ontario, Canada. Only 38% of Grade 8 students were taught by a teacher who largely studied science during his/her university years. Compared to other Canadian provinces (56% for Alberta and 69% for Québec), and the international average (79%), elementary school teachers in Ontario are not as well qualified to teach science. Additionally, only 55% of Grade 4 students in Ontario were taught by teachers who indicated that they considered themselves “very well” prepared to teach TIMSS science topics compared to 66% in Alberta, 41% in Québec, and 62% internationally. For Grade 8, the percentage of students taught by teachers who felt “very well” prepared to teach TIMSS science topics was 61% in Ontario, 72% in Alberta and internationally, and 71%

in Québec. Thus, not only are teachers in Ontario not as qualified to teach elementary school science as their other counterparts across Canada and internationally, they do not feel as well prepared either. The lack of teacher qualifications and preparedness to teach elementary school science was reflected in the 2011 science scores of Grade 4 and 8 students in Ontario. Concerning Grade 4, the Ontario results “improved significantly between 1995 and 2011. The 2011 average scale score is significantly higher than in 1995, but significantly lower than in 2003” (p. 16). Regarding the Grade 8 results, they steadily improved up until 2003 and declined onward. However, the 2011 results were still “significantly higher than the 1995 average” (p. 16). Due to the decline in science scores, Ontario’s international standing in science achievement declined from 2007 to 2011. When considering Ontario’s science achievement standing, 51% and 63% of the science items are covered by Grade 4 and 8 in the Ontario curriculum. Furthermore, “when the Ontario averages are computed excluding the items that are not covered, there is no significant difference in the average. The curricula of many of the top performing countries cover fewer items than Ontario’s does” (p. 16).

Section 2: Collaborative Professional Learning for Science Education

The challenges that teachers face with implementing inquiry teaching for science education will persist (Crawford, 2014) unless teachers become engaged in authentic science activities in their school environment to further their science learning and teaching. Meaning, teachers need to engage in ongoing and effective collaborative professional learning within the school environment that adopts a participatory and social constructivist-oriented approach. There are several titles for collaborative professional learning. For example, Weißenrieder, Roesken-Winter, Schueler, Binner, and Blömeke, (2015) provided a list of various titles for the term “professional learning community” that included: *teachers’ collaboration with colleagues*, *professional community*, *communities of inquiry*, and *communities of practice*. Other names include *norms of collegiality* (e.g., Little, 1982, 1990), *learning community* (McLaughlin & Talbert, 2001) *teacher networks* (e.g., Adams, 2000; Lieberman & McLaughlin, 1992a, 1992b; Lieberman & Wood, 2002a, 2002b; Smith & Wohlstetter, 2001), *Network Learning Communities* (Jackson & Tasker, 2002), *Team-based schooling* (e.g., Lachance & Confrey, 2003), and *Fostering a Community of Learners* (e.g., Brown & Campione,

1992, 1996). A reason for the extensive list of varying names is that a universal definition fails to exist (Cranston, 2007; Hord, 1997; Stoll, Bolam, McMahon, Wallace, & Thomas, 2006; Toole & Louis, 2002) and there are numerous authors who write about collaborative professional learning and use their terms (Plank, 1997). Although the names differ, the foundations are similar.

Opfer and Peddler (2011) described professional learning as a complex and iterative interaction between teachers, the school, and the activity in which they engage. The Ontario Ministry of Education explained that professional learning must be coherent, attentive to adult learning styles, goal-oriented, sustainable, and evidence-informed (Ontario Ministry of Education, 2007). As such, teacher learning is a predominate issue in educational policy and practice (Nova Scotia Department of Education & Early Childhood Development, 2011). In both educational research and practice, professional learning is said to remain an “urgent and relevant topic” (Enthoven & de Bruijn, 2010, p. 289), as in general, there is a disconnect between research and practice (Butler & Schnellert, 2010). It is supposed to, in part, help teachers become lifelong learners (National Research Council, 1996), and to help teachers learn about and teach using inquiry-based strategies (Oliveira, 2010; Schneider & Plasman, 2011). For instance, Darling-Hammond and colleagues (Darling-Hammond, Chung Wei, Andree, Richardson, & Orphanos, 2009a) explained the outcomes of “effective” professional learning relate to the improvement of teacher knowledge and instructional practice, and improved student learning.

Moving forward, the support for professional learning for science education is discussed. Research conducted by the Ontario’s Principal Council (2009) posits that professional learning communities are an instrument for the enhancement of learning, teaching, and leadership capacity at all levels of the education system. Regarding educational researchers, several have supported the notion of effective collaborative professional learning. For example: (a) Luft and Hewson (2014) said that one means is to have teachers actively engaging in effective collaborative professional learning that is situated within the dynamic context of the school environment; (b) Fazio and Karrow (2013) state that to improve the current state of elementary science education, “promoting science teacher education and development practices that are collaborative and practice-

oriented are essential”; (c) Halverson, Feinstein, and Meshoulam (2011) expressed that central to teacher learning opportunities related to science education is their engagement in reform-oriented, ongoing professional learning; and (d) researchers such as Guskey (1986, 2002) and Wilson (2013) expressed that high-quality and effective professional learning is essential to improving science education.

Key characteristics of collaborative professional learning. Even though a universal definition and characteristics fail to exist (Stoll et al., 2006), there are similar aspects of collaborative professional learning that are noted by several researchers (e.g., Bouchamma & Michaud, 2014; Desimone, 2009; van Driel, Meirink, Van Veen, & Zwart 2012; Wilson, 2013; Zhang et al., 2015). For instance, Zhang and colleagues (2015) summarized a broad consensus of features that should be included for effective professional learning such as: informed by learning theories; intensive, sustained and ongoing learning; focus on content and curriculum; opportunities for rich and active learning; collaboration with other teachers, preferably from the same school; connected to teachers daily practice and their own learning goals; and aligned with local, state, and national standards and objectives (see p. 474).

Noteworthy is Desimone (2009), who is known for her article, *Improving Impact Studies of Teachers’ Professional Development: Toward Better Conceptualizations and Measures*, outlines features for studying professional learning amongst educators. The framework illuminates a situated perspective about teacher learning and learning to teach through participating in collaborative professional learning, with the ultimate goal of teachers becoming more knowledgeable in, and about, teaching to improve student learning. The empirically grounded, interactive and non-recursive framework reflects the relationship between critical features of professional learning, teacher knowledge, beliefs and attitudes, classroom practice, and student outcomes (Desimone, 2009). Desimone (2009) suggests four steps for high-quality professional learning: (a) teachers experience high-quality professional learning; (b) teacher knowledge and skills, and/or changes in their attitudes or beliefs increase with high-quality professional learning; (c) teachers new knowledge, attitudes, and beliefs can change teaching instruction, or their pedagogy, or both; and (d) instructional changes can result in improving student learning. Below, the core features of Desimone’s model are discussed.

Content focus. Desimone (2009) explained that empirical studies have shown content focused professional learning enhances teacher knowledge, reforms teaching practice, and improves student learning. Below is a brief overview of research about four forms of teacher knowledge that are discussed in detail by Abell (2007) in her article titled, *Research on Science Teacher Knowledge*.

Subject Matter Knowledge. Subject Matter Knowledge can either stem from substantive and/or syntactic knowledge – both components of content knowledge (Shulman, 1987). Substantive content includes knowledge of general concepts, principles and conceptual schemes, theories, ideas, organizational frameworks and proof all related to a science topic (Hashweh, 2005). Syntactic knowledge is beliefs about the nature of scientific knowledge, its philosophy, history, generation, validation, and dissemination (Hodson, 2009). The research regarding the effectiveness of Subject Matter Knowledge in professional learning activities has been debated. On the one hand, research has shown that learning science knowledge alone does not lead to elementary teachers being more effective science teachers (Schibeci & Hickey, 2000). Reasons include that their factual recall is not as important as their understanding of science as a discipline for student achievement (Duschl et al., 2007). And, Diamond, Maerten-Rivera, Rohrer, and Lee (2014) found that professional learning that was focused primarily on science knowledge had a minimal but positive effect on teacher knowledge; however, the improvement in teacher knowledge was not observed in classroom practice. It should also be noted that when discussing science education and teachers, teachers science knowledge was once viewed from a quantity perspective or how many science courses they completed, which may have skewed the research findings about the depth of teachers science knowledge and the relation between science Subject Matter Knowledge and teaching (Abell, 2007). On the other hand, researchers (e.g., Cohen & Hill, 2000) have claimed that without professional learning having a strong content component, it can be relatively ineffective in changing teaching practices. And others (e.g., Desimone, 2011; Garet et al., 2001; Kennedy, 1998) showed that content focus has been considered as the most influential factor influencing ongoing professional learning from case-study data, correlational analyses, and quasi-experimental studies.

Pedagogical Knowledge. Pedagogical knowledge includes “knowledge of instructional principles, classroom management, learners and learning, and educational aims that are not subject-matter-specific” (Abell, 2007, p. 1120). Most literature regarding pedagogical knowledge for science education is placed under the category of pedagogical content knowledge because it is specific to the science domain.

Pedagogical Content Knowledge. A growing number of scholars have worked on the concept of Pedagogical Content Knowledge since its inception (e.g., Geddis, Onslow, Beynon, & Oesch, 1993; Grossman, 1990; Hashweh, 2005; Loughran, Gunstone, Berry, Milroy, & Mulhall, 2000; Loughran, Berry, & Mulhall, 2006; Magnusson, Krajcik, & Borko, 1999; Marks, 1990; van Driel, Verloop, & De Vos, 1998). Nonetheless, Goodnough (2008) claimed that for teacher education, Pedagogical Content Knowledge is also most commonly defined by Lee Shulman (1987). Shulman’s (1987) idea of Pedagogical Content Knowledge was that it served as:

An amalgam of content and pedagogy into an understanding of how particular topics, problems, or issues are organised, represented and adapted to the diverse interests and abilities of learners, and presented in instruction [and was comprised of] the ways of representing and formulating the subject that makes it comprehensible to others. (pp. 8-9)

While strong subject matter knowledge is essential to develop Pedagogical Content Knowledge for science (e.g. Abell, 2007; de Jong & van Driel, 2004; Halim & Meerah, 2002), it alone is not sufficient for effective teaching. Pedagogical Content Knowledge “goes beyond knowledge of subject matter per-se to the dimension of subject matter knowledge for teaching” (Shulman 1987, p. 9). It involves a dramatic shift in teacher understanding of subject matter “to becoming able to elucidate subject matter in new ways, reorganize and partition it, clothe it in activities and emotions, in metaphors and exercises, and in examples and demonstrations, so that it can be grasped by students” (Shulman, 1987, p. 13). Pedagogical Content Knowledge is regarded as “the professional knowledge base of science teachers that distinguishes them from scientists” (Chan & Yung, 2015, p. 1247). Teachers should adapt subject matter knowledge for pedagogical purposes and prepare it for effective instruction through a process Shulman (1987) called “transformation”, Ball (1990) labelled “representation”, Veal and MaKinster (1999)

termed “translation”, Bullough (2001) named “professionalizing”, and Dewey (1902/1983) called “psychologizing”.

Some researchers (e.g., Davis & Krajcik, 2005; Veal & Kubasko, 2003) view Pedagogical Content Knowledge as a generic level, discipline specific concept; however, more widely accepted is the notion that Pedagogical Content Knowledge concerns the teaching of specific topics (van Driel et al., 1998; Hashweh, 2005). For instance, Hashweh (2005) suggested that Pedagogical Content Knowledge grows from the experiences teachers have teaching a topic and then new Pedagogical Content Knowledge develops as they construct new analogies for explaining concepts. So Pedagogical Content Knowledge is expanded and elaborated with teaching practice, or as knowledge is refined in the teaching process (Chan & Yung, 2015). Either way, Pedagogical Content Knowledge is developed, it is not an innate concept (Kind, 2009). Also, researchers (e.g., Magnusson et al., 1999; van Driel et al., 1998) have defined Pedagogical Content Knowledge with various components (see Goodnough & Nolan, 2008). For instance, the development of Pedagogical Content Knowledge also involves reflection in real time, or reflection-in-action, or after instructional practice (reflection-on-action), which is described by Schön, (1983, 1987).

Regarding professional learning, there is a growing consensus that Pedagogical Content Knowledge should be the primary focus (Bausmith & Barry, 2011; Hashweh, 2013; van Driel & Berry, 2012) considering that there have been calls to improve science teaching through improving their Pedagogical Content Knowledge (Kind, 2009). The problem is that in practice, professional learning in education is yet to be topic-specific (Zhang et al., 2015). Yager (2005) emphasized that “one of the most serious problems concerning professional development is the fact that schools often plan general workshops with general leaders – all seemingly having little to do with specific curriculum components or day-to-day teaching” (p. 99). Parallel to Yager’s findings, Hashweh (2013) stated that “research on teacher learning and development ... still views teacher learning as a generic activity and neglects the domain or discipline specificity of teacher learning and development” (p. 136).

Knowledge of Context. Knowledge of context includes the background of students, the school, community and district (Abell, 2007). This form of knowledge is

situational and “rooted in the day-to-day experience of particular educational situations” (Barnett & Hodson, 2001, p. 439).

Active Learning. Participating in effective professional learning should provide teachers with opportunities to be actively engaged in furthering their teaching and learning (Desimone, 2009) by means of: observing other teachers or being observed followed by interactive feedback and reflective discussions; reviewing student work to provide further facilitation in areas that students struggle; marking assessments followed by interactive feedback and discussion; developing and presenting lessons; and interacting with fellow teachers to discuss steps to improve teaching practice (e.g., Banilower & Shimkus, 2004; Blank, de las Alas, & Smith, 2008; Borko, 2004; Corcoran, 2007; Desimone, 2002, 2009).

Coherence. Coherence is the extent to which teacher learning opportunities are consistent with their knowledge and beliefs (Mokhele, 2013), and with school and district policies (Desimone, 2009; Garet et al., 2001). Another aspect of coherence is amongst teachers and their relationships. When teachers discuss and brainstorm ideas amongst themselves, implement new techniques in their practice, provide each other with constructive feedback, and share student reactions, they can successfully implement what they learn in professional learning (Cochran-Smith & Lytle, 1999). Garet et al. (2001) found coherence was positively related to changes in teaching practice when researching three dimensions of teachers: (a) the extent to which professional learning was consistent with goals teachers held, (b) the degree to which professional learning activities were aligned with state and district standards and assessments, and (c) the extent to which professional learning promoted communication among teachers about their work. Lastly, Penuel et al. (2007) investigated the effectiveness of professional learning on curriculum implementation with a sample of 454 science teachers. A finding was that teachers advocated for coherence in professional learning and their learning and teaching goals: “teachers’ interpretations of how well aligned the PD [professional development] activities are with their own goals for learning and their goals for students” (p. 931). Greater coherence had a positive effect on curriculum implementation. Thus, Penuel et al.’s study demonstrated that professional learning should be a response to the learning and teaching needs of teachers.

Collaboration. A feature of professional learning is collaborative participation - referring to multiple teachers from the same school, grade, or department participating in similar learning opportunities (Hochberg & Desimone, 2010; Mokhele, 2013). The concept of collaboration engages teachers, principals, and other administrators in co-learning processes and the opportunity to learn and consider the perspective of others to further refine their understandings (Lee, 2009). Collaborative participation also leads to discourse between educators and possibly administrators, which is a powerful resource for teacher learning (Banilower & Shimkus, 2004; Borko, 2004; Desimone, 2003). The collaborative process of deconstructing and reconstructing knowledge with colleagues signifies how collaboration within collaborative professional learning is designed with a social constructivist approach to learning. The diversity of perspectives and expertise shared helps educators reach better decisions (Surowiecki, 2005). For instance, Wenger (2000), whose work is underpinned by social constructivism, believes that within such collaborative professional learning, practice is developed and refined through the collaboration of teachers sharing common concerns, problems or interests, and who develop their knowledge by continuously and regularly interacting. Also, Vescio, Ross, and Adams (2008) found 11 studies that reported increased collaboration, teacher empowerment, and continuous learning that resulted in increased teacher learning, and that translated into improving teacher instructional practice and student outcomes. Notably, collaboration is easier in theory than in practice because the collaborative process can prove to be demanding and personally challenging (Mandzuk, 1999). Even though collaboration is extremely hard to master, it is key to the implementation of high-quality professional learning given that collaborative inquiry that challenges thinking and practice is the *how* of teacher professional learning (Katz & Dack, 2013).

Research has shown that teachers who engage in collaborative practices have increased teaching self-efficacy and satisfaction (Day, Kington, Sobart, & Sammons, 2006; Flores & Day, 2006) and develop refined values, beliefs, norms, and preferred behaviors (Fullan, 2007; McLeskey & Waldron, 2000, 2002a, 2006). A collaborative culture leads to higher levels of trust and respect among colleagues, improved instructional practices, and better outcomes for students (Dufour, Dufour, Eaker, & Many, 2006; Fisher & Frey, 2003; Friend & Cook, 2007). Reasons for these effects are

that collaborative environments can provide a means for teachers to take part in shared problem solving, decision making, data analysis, and distributed leadership (McLeskey & Waldron, 2000; Walther-Thomas, Korinek, McLaughlin, & Williams, 2000). Lastly, Lee, Songer, and Lee (2006) found that when reforms are implemented by a group of teachers, the reform is less vulnerable to external pressures and are easier to sustain.

Duration. Desimone (2009) stated that altering knowledge and pedagogy requires teachers to dedicate sufficient time to their professional learning. Desimone (2009) explained that the aspect of time is the “span of time over which the activity is spread (e.g., one day or one semester) and the number of hours spent in the activity” (p. 184). Conclusive research fails to exist regarding a definite length of time needed for professional learning to be effective. However, research has shown that longer durations of professional learning activities are more likely to encourage in-depth discussions about content, student conceptions, and misconceptions (Desimone, 2009) and are more effective in changing teachers practice (e.g., Banilower et al., 2007; Boyle, Lamprianou, & Boyle, 2005; Gerard, Varma, Corliss, & Linn, 2011).

In terms of science education, the benefits of teacher engagement in collaborative professional learning do not develop quickly (Ratcliffe & Millar, 2009). Studies have shown that the benefits of collaborative professional learning related to elementary science education largely revolved around effective collaborative professional learning that is ongoing and sustained for a long duration of time. For instance, a study by Lewis et al. (2015) found that teachers who participated in a professional learning program for longer periods of time than newly participating teachers implemented more strategies they learned and had higher rates of changing their science practice. In 2011 by Gerard et al. looked at 43 empirical, peer-reviewed research studies about professional learning in technology-enhanced science education for the past 25 years. The authors defined “long-term” as programs that were longer than one year. They reported that: “long-term professional development programs focused on helping teachers to integrate the technology into their practice to enhance students’ inquiry science learning” (p. 419). Various reasons for prolonged professional learning being beneficial to both teacher and student learning was that teachers had the time to learn about the technologies for specific topic units, integrate the technology into the curriculum, and customize their practice

according to student needs. Meaning, teachers were able to better able to formulate questions that helped students understand a scientific phenomenon from multiple “representations in the technology-enhanced materials” (p. 424). And, the teachers improved their feedback according to the student’s needs. Overall, the authors concluded that professional learning programs that “support teachers to engage in a comprehensive, constructivist-oriented learning process can improve students’ inquiry science learning experiences” (p. 438). Capps and Crawford (2013) also stated that for collaborative professional learning to be effective, teachers need time to engage in the activities and teachers need time to reflect on their learning from professional learning sessions before implementing inquiry teaching. Similarly, a study by Johnson, Kahle, and Fargo’s (2007) was longitudinal and included middle school science teachers. They addressed the relationship between their 3-year engagement in whole-school collaborative professional learning and student achievement in science. The results showed a significant relationship between student achievement in science and teacher engagement in the learning activities. Notably, the positive effects were found two and three years, not one year after teachers engaged in the learning activities. The authors suggested that the delay may be a result of teachers needing time to integrate their learning into their practice. Next, from an analysis of nine rigorous studies identified from the systematic review of professional learning impact studies, Yoon and colleagues (Yoon, Duncan, Lee, Scarloss, & Shapley, 2007) found the duration of professional learning activities had an effect on student learning. Out of six studies that provided sufficient contact hours of professional learning, the general range of hours needed to depict a statistically significant and positive effect on student achievement gains were 30 to 100 hours. The remaining three studies found 5 to 14 hours of professional learning activity showed no statistically significant effect on student learning. Yoon and colleagues considered professional learning to include a combination of traditional workshops, summer institutes and conferences, reform types including coaching and mentoring embedded in classroom teaching, and online professional learning courses with virtual teacher-learning communities. Lastly, Supovitz and Turner (2000) analyzed cross-sectional data from 24 Local Systemic Change initiative that involved the K-8 science component from the National Science Foundation Teacher Enhancement program. Briefly, the Local Systemic Change initiative was meant

to support teacher's improvement to their science teaching. They found that to increase inquiry-based science practices, at least 80 hours of high quality professional learning are needed for teachers to establish an investigative classroom culture. Notably, the 24 initiatives involved in the research had science teachers participate in a wide range of high quality professional learning whereby some teachers were provided training, some relied on volunteers and provided incentives. Some teachers participated more intensely than others such that some teachers in the initiatives did not receive any professional learning (see Supovitz & Turner, 2000, p. 968).

Although it has been shown that teachers need to be continually engaged in collaborative professional learning for a prolonged period of time, studies have shown that this is problematic because that time is not always available. For instance, Brand and Moore (2011) studied 30 K-5 teachers implementation of inquiry science teaching in the classroom. Key to their findings was that time was a limiting factor for teachers to engage in professional learning to learn about and apply inquiry teaching. The lack of time was also addressed by Jones, Gardner, Robertson, and Robert (2013). They studied a total of 65 elementary teachers (K-5) who taught science and participated in collaborative professional learning activities related to science. The authors expressed that:

Time was a major constraint on the effectiveness of science PLCs that was mentioned by almost all the teachers. Within the theme of time, some teachers noted there was not enough time, their time in PLCs was interrupted by administrators, and that PLC meetings were rushed. For others, the time in PLCs was viewed as wasted or of such a short duration that little was effectively accomplished. (p. 1768)

Lastly, although the research literature has identified that professional learning opportunities can produce fundamental changes in teacher knowledge, beliefs and practice (Lumpe Czerniak, Haney, & Beltyukova, 2012; Rushton, Lotter, & Singer, 2011), these changes can be counteracted by a short duration of professional learning (Borko, 2004) followed by a lack of fiscal resources to support follow-ups (Lee, Hart, Cuevas, & Enders, 2004).

The effectiveness of collaborative professional learning. Coupled with the benefits of long-term collaborative professional learning, more specific benefits of collaborative professional learning are as follows. First, research has shown an increase

in student achievement. For instance, Yoon and colleagues (2007) identified 1,300 studies that addressed the effectiveness of in-service professional learning for teachers on student achievement in science, reading, and mathematics. A total of nine studies met the standards for “evidence without reservation” in the What Works Clearinghouse standards - all of which focused on elementary teachers. Intense and sustained professional learning was directly related to student achievement in science, reading, and mathematics. A second example was a study conducted by Lee, Deaktor, Enders, and Lambert, (2008). The authors found that after third, fourth, and fifth grade teachers from six elementary schools in a large urban school district participated in a 3-year professional learning program, the science achievement of culturally and linguistically diverse elementary students improved at the end of each school year – measured by the Trends in International Mathematics and Science Study assessment.

Secondly, there have been studies to show that prolonged engagement in collaborative professional learning helps to improve teachers’ confidence to teach science using inquiry-based investigations that align with curriculum requirements, and to alter their beliefs about science education which may help to orient their classroom teaching to a student-centered approach. For example, Cotabish, Dailey, Hughes, and Robinson (2011) found that after elementary teachers engaged in embedded professional learning within the school for two years, they were better able to design science investigations in the context of real-world problems compared to teachers who did not participate in professional learning. Also, the teachers who participated had an increased sense of confidence to guide students through the scientific process. Next, based on Pedretti and Bellomo (2013) findings from a group of 24 elementary teachers in Ontario, Canada who were focusing on science, technology, society, and environmental (STSE) objectives in a professional learning community, participation provided “a supportive and engaging environment where educators could freely *begin* to discuss and share ideas about STSE education and feel more confident in their abilities to negotiate and implement the new STSE curriculum requirements” (p. 434). Notably, teachers considered the community as a means for “professional growth and development, and a space for challenging views and practices” (p. 434). So, the professional learning community was successful at narrowing the gap between curriculum implementation stemming from policy, and

professional development in the Ontario elementary school context regarding science education. Lastly, Smith (2015) conducted a 2-year professional learning program with primary teachers in a rural area of Ireland to focus on their content knowledge and attitudes toward science and to change their instructional practice. Their findings supported other research findings (e.g., Darling-Hammond, Chung Wei, Andree, Richardson, & Orphanos, 2009b; Desimone, 2009; Garet et al., 2001) by demonstrating that when teachers engage in effective professional learning, their classroom practice and attitudes toward learning primary science can change. The study participants shifted their science instruction away from teacher-centered to more student-centered approaches - likely because teachers were more confident and competent in their science teaching (Smith, 2014), so teachers began teaching hands-on, inquiry-based science (Smith, 2015).

Regardless of the benefits of collaborative professional learning, in general, Wenger, McDermott, and Snyder (2002) suggested that collaborative professional learning cannot be romanticized. In terms of trust, teachers are unlikely to participate in classroom observation and feedback, mentoring partnerships, discussion about pedagogical issues, and curriculum innovation unless they feel safe. Trust and respect from colleagues is critical (Tschannen-Moran, 2009). If a level of trust amongst colleagues is absent when issues arise, teachers often react by feeling confused and personally attacked, and they often respond by distancing themselves from their colleagues (Hargreaves, 2001). Bryk, Camburn, and Louis (1999) also noted that when teachers respect and trust each other, together they are powerful resources to assisting one another by deprivatizing practice and participating in reflective dialogue. Another reason as to why collaborative professional learning cannot be romanticized is that teachers and administrators have been accustomed to traditional professional learning that is viewed as “one shot workshops” that are: fragmented and superficial (Colantonio, 2005; Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003); irrelevant or disconnected to the real work teachers do in the classroom and misaligned with their specific needs for improvement (e.g., Borko, 2004; Goodnough & Nolan, 2008; Liberman & Pointer Mace, 2008; Rotherham et al., 2008); are perceived as ineffective (e.g., Desimone, Smith, & Phillips, 2007; Pianta, 2011); and have little to no follow-up (e.g., Pianta, 2011; Spillane, 2002). Also, schools are, and have been, structured to emphasize teacher isolation by

rarely providing the time for teachers to work together to plan lessons, create assessments, discuss evaluations and assist administrators in making decisions (Darling-Hammond et al., 2009b). Additional factors that may influence limitations to the effectiveness of collaborative professional learning include a fear of change and reduced autonomy, limits on the number of days or hours teachers can be out of the classroom for training, difficulty finding adequate substitute coverage, demands for high-stakes assessment preparation and resources, lack of sustained professional learning, and teacher beliefs about teaching and learning (Blanchard, Southerland, & Granger, 2009; Luft, 2007).

Section 3: External and Internal Contextual Factors Influencing Teacher Engagement in Collaborative Professional Learning for Science Education

Context is an important factor when addressing teacher's high-quality professional learning (Borko, 2004). Dufour and Eaker (1998) argued that in the right context, even flawed professional learning initiatives can have a positive effect on teacher learning. Inversely, in the wrong school context, "well-conceived and delivered activities are likely to be ineffective" (p. 25). Loughran (2014) emphasized that within the context of science education, collaborative professional learning can improve teachers understanding of science when activities are "well-designed" (p. 816). But, to have effective collaborative professional learning within a school environment, Loughran emphasizes that contextual factors need to be taken into account:

We need to look into the past, to understand that simply creating policy documents and new curricula, *without attention to robustly supporting teachers*, will not necessary change the way we traditionally teach science. Science teacher education needs to change as well. PD programs for practicing teachers need to be designed with attention to the context of school, teachers' backgrounds and beliefs, and grade level and culture of students. And we need to pay attention to policy issues and remove the roadblocks that prevent change from happening. (p. 537)

Below, contextual factors that can influence science teachers to engage in professional learning to enhance their science learning and classroom are discussed. Specifically discussed are factors related to external influences related to provincial and national

policies, the local school, the leadership of the school principal and teachers (beliefs, self-efficacy, and pedagogical discontentment).

External influences related to policy. Hardy (2012) claims that teacher professional learning and support for such practices is inherently political because the focus is on the implementation of province-wide educational policy and the specific needs of teacher professional practice that is meant to improve student achievement. It is necessary to acknowledge political factors to understand the implementation of teacher collaborative professional learning situated within school settings.

Political influences affecting professional learning related to science education in Ontario, Canada. Teacher engagement in collaborative professional learning has become increasingly important as policy documents around the globe have “articulated the need for science teachers to receive ample professional development opportunities in order to enhance and improve their knowledge and practices” (Luft & Hewson, 2014, p. 890). The reason for improving teacher science knowledge and pedagogy is that policies call for students to become scientifically oriented citizens and for teachers to shift toward the use of inquiry teaching strategies for learning and teaching science education (Crawford, 2014). Also, the Ontario Ministry of Education, Finland, Lebanon, the United States, Israel, Venezuela, Australia and Taiwan have advocated for these changes in their policies toward the teaching of elementary school science (Crawford, 2014). In Canada, a national education curriculum fails to exist: the 10 provincial governments and three territories develop independent educational decisions. However, Roberts and Bybee (2014) explained that the,

... science curriculum revision has been stimulated by a nationwide “framework” (Council of Ministers of Education, Canada [CMEC], 1997) to which provincial ministers of education subscribed in hopes of providing common ground and more consistency in learning outcomes for school science across the country. The framework “is guided by the vision that all Canadian students, regardless of gender or cultural background, will have an opportunity to develop scientific literacy” (p. 4). Scientific literacy (SL) is defined as “an evolving combination of the *science-related* attitudes, skills, and knowledge students need to develop *inquiry, problem-solving, and decision-making abilities*, to become lifelong learners, and to maintain a sense of wonder about the world around them. (p. 548)

Professional Activity Days. In the Ontario Education Act, titled, *Revised Regulations of Ontario, 1990, c. E.2, Regulation 304: School year calendar, professional activity days* (referring the amendment from November 30th, 2015), the rules for professional activity days are outlined. First, professional activity days are school days within the school calendar that are designated for educators to engage in professional activities. More specifically, school days are not on holidays, and are within the school calendar year (after September 1st and before June 30th). Included in the minimum of 194 school days, each school board shall designate three days for professional activity days. In addition to the three full days, up to four full days can be designated by the local school board for professional activity days.

Literacy and Numeracy Secretariat. The Literacy and Numeracy Secretariat will be discussed concerning teacher learning. Hardy (2009) explained that since 1998, increased interest in Ontario's student literacy and numeracy capabilities has come from the Education Quality and Accountability Office's (EQAO) test results. In response to concerns about the results of these tests, in 2003, the Liberal Governments Ministry of Education financially and actively supported professional learning targeted at improving student literacy and numeracy. This led to the establishment in 2004 of a separate body – the Literacy and Numeracy Secretariat – within the Ontario Ministry of Education who is answerable directly to the Deputy Minister of Education. As a result of these actions, Volante (2004) worries that teacher learning may be limited to activities narrowly focused on “teaching to the test” (p. 1), meaning literacy and numeracy on the EQAO. An academic participant from Hardy's (2009) study about the influence of principals on teacher professional learning in Ontario spoke about how the political push for numeracy and literacy has affected teacher professional learning in other subject areas and how it has been neglected. The participant explains that there is a disconnect for teachers teaching subjects with limited government support. Another participant continued to say that teacher professional learning needs to take specific contexts into account regarding the concerns and needs of teachers and students learning. More currently, as Ken Thurston, the York Region District School Board director of education said: “literacy continues to be a key priority for the York Region District School Board. It is the ever-evolving underpinning of our society and fundamental to what we wish to achieve in

public education” (Belchetz & Witherow, 2014, p. 19). Also, Giles and Hargreaves (2006) argue that the pressures of accountability have led public education systems to foster teacher learning communities. However, teacher learning has narrowly focused on improving standardized measures of learning focused on numeracy and literacy, rather than supporting broader conceptions of teacher learning where it is most needed in the individual school context.

Lastly, the Ontario Literacy and Numeracy Secretariat values teacher professional learning cultures and enhanced student learning, so they implemented Collaborative Inquiry programs in elementary schools (Ontario Ministry of Education, Capacity Building Series, September 2014; Ontario Literacy and Numeracy Secretariat, 2007, 2010). The Literacy and Numeracy Secretariat heavily encourages Collaborative Inquiry for teachers to foster reflection and to take an “inquiry stance” by making informed decisions through evidence, targeting student needs through various assessment strategies, and using descriptive and constructive feedback. The concept of Collaborative Inquiry supports professional learning cultures on an ongoing basis as it provides educators autonomy to collaborate, collect, analyze, and summarize data from multiple sources, and use that evidence to support their professional learning (see Ontario Ministry of Education, Secretariat Special Edition, Capacity Building Series, Collaborative Teacher Inquiry, September 2010). Collaborative Inquiry is underpinned by a socio-constructivist philosophical approach to inquiry as it emphasizes dialogical sharing (shared participation, shared responsibility, shared leadership, shared values, goals and vision), taking action (teachers changing their instructional strategies to try new approaches; discussing teacher beliefs), and reflecting (Bolden et al., 2014). The Ontario Literacy and Numeracy Secretariat, (2007a) stated that reflection can occur at the individual level and it is fundamental to provoking learning that will change practice (Ontario Literacy and Numeracy Secretariat, 2007, 2010; Ontario Ministry of Education, 2007). The three main reasons for emphasizing Collaborative Inquiry is to improve student achievement, reduce achievement gaps, and increase confidence in public education – to meet the needs of the education-improvement strategy (Energizing Ontario Education) put in place in 2004. Presently, there are four collaborative inquiry initiatives: Collaborative Inquiry for Learning Mathematics (CIL-M), Early Primary Collaborative

Inquiry K-2 (EPCI), System Implementation and Monitoring (SIM), and the Student Work Study Teacher (SWST) initiative. However, successful implementation of the Collaborative Inquiry model is challenging (Kasian, Klinger, Maggi, & D'Angiulli, 2010). Although these programs have been implemented, Bolden et al. (2014) highlighted that: (a) it is unknown whether these initiatives are “effective professional learning model[s] in Ontario elementary schools” (p. 8); (b) there is insufficient research and evidence supporting ways to maintain Collaborative Inquiry as a means of professional learning within schools and school districts in Ontario; and (c) the identification of ways to overcome challenges facing Collaborative Inquiry is necessary. Challenges identified were “cultural buy in, leadership, temporal constraints, and data literacy” (p. 29). Overall, educational reform for teacher professional learning in Ontario, Canada has been influenced by a multitude of factors including provincial legislation and associated policies for educational reform (Hardy, 2009).

School context influences. It is believed that situating professional learning within the school environment optimizes its effectiveness (Dufour, 2004) by establishing an ideal context to improve the knowledge and skills of teachers, change teaching practices, and improve student achievement (Desimone, Smith, & Ueno, 2006). For successful engagement in collaborative professional learning, helpful influential factors include scheduled time in teacher timetables, strategically distributing staff members and resources, developing confidence and mutual support amongst staff members, and supporting an environment for professional learning (Leclerc, Moreau, Dumouchel, & Sallafranque-St-Louis, 2012). Regarding a supportive environment, the culture of the school may have a greater influence over teacher learning than professional learning activities or programs (Luft & Hewson, 2014). Other factors that influence teacher professional learning are the school size and particular mix of teachers. For instance, Lee, Smith, and Bryk (1993) found that smaller schools led to more engaging work environments for teachers and students. On the contrary, in larger schools with lots of staff, it is more difficult for staff to identify with one another and create a community (Huberman, 1993). Bryk, Camburn, and Louis (1999) added that the size of the school affects the social dynamics, communication flow, and face-to-face interactions.

Leadership of school principals. School leadership plays an important role in teacher participation in professional learning activities and teacher instruction for science (Banilower et al., 2007; Corcoran, Fuhrman, & Belcher, 2001). In fact, principal leadership ranks second beside classroom instruction amongst all potential factors contributing to student learning at school (Leithwood, Louis, Anderson, & Wahlstrom, 2004). Due to the insurmountable evidence regarding the benefits of effective leadership and that leaders are the main providers of professional learning, Whitworth and Chiu (2015) proposed that school and district leadership should be “emphasized more” in Desimone’s (2009) model of professional learning. Whitworth and Chiu placed the leaders at the start of the path toward student achievement, rather than as part of the context in Desimone’s pathway (see Figure 2, p. 129). Also, Whitworth and Chiu (2015) stated that because of the predominance of leadership in professional learning, “it is critical to understand school and district leaders’ views of professional development, and their practices, and the factors that influence school and district leadership in choosing and designing professional development” (p. 130). Other factors that are also important to understand the leadership role of the school principals and their facilitation and/or guidance of professional learning is understanding “how principals organize schools, and the work they coordinate to develop a context that leads to a strong sense of collective efficacy, high trust, a steadfast press for academics, and a professional climate” (Tschannen-Moran, Salloum, & Goddard, 2015, p. 309).

Principals must first create a culture that is conducive to teacher learning. The reason is that principals are responsible for setting the conditions for teacher learning by “managing school resources, relate to teachers and students, support or inhibit social interaction and leadership in the faculty, respond to the broader policy context, and bring resources into the school” (McLaughlin & Talbert, 2001, p. 98). Included in setting the optimal conditions for professional learning is the principal creating cultural norms that foster positive learning interactions which lead to positive beliefs about teacher learning and teaching (Tschannen-Moran et al., 2015). Next, principals play a critical role in managing external and internal accountability systems by supporting the teachers to align their instruction with the goals of the school (Schleicher, 2012). To enable teacher practices, principals can help create a mutually agreed-upon school vision and specific

goals for student learning (Dufour, 2006); prioritize the professional growth of teachers to work collaboratively (Murphy & Lick, 2005); and to ensure teachers receive learning opportunities that expand their practitioner knowledge and instructional repertoire (Murphy & Lick, 2005). Also, to support teacher learning, principals should be co-learners and help analyze student data with teachers and provide teachers with scheduled time for uninterrupted meetings, space, resources to support their ideas, encouragement, and professional learning (Drago-Severson, 2004; Ermeling, 2010; Richardson, 2007; Slavit, Nelson, & Kennedy, 2010).

Emihovich and Battaglia (2000) explain that as models of professional learning change over time from traditional to reform-based, there is also a need to change the style of leadership. Researchers (e.g., Branch, Hanushek, & Rivkin, 2012; Coelli & Green, 2012; Grissom, Kalogrides, & Loeb, 2012) have documented variations in principal effectiveness across schools that highlight behavioral factors that lead some principals to be more effective than others. Through the mid-1980's, the concept of instructional leadership was key to successful instructional improvement (see, for example, Berman & McLaughlin, 1978; Bossert, Dwyer, Rowan, & Lee, 1982; Edmonds, 1979; Leithwood & Montgomery, 1982; Lipham, 1981; Hallinger & Murphy, 1985) and student achievement (e.g., Matthews & Crow, 2010; Hargreaves & Fink, 2003; Sergiovanni, 2006; Lynch, 2012). Strong instructional leaders are “hands-on leaders, engaged with curriculum and instruction issues, unafraid to work directly with teachers, and often present in classrooms” (Horng & Loeb, 2010, p. 66), and are committed to ensuring collaborative professional learning is active and enables teachers to partake in pedagogical learning activities, collaboration, and peer supervision to provide the best learning opportunities for students (Hopkins, 2003). When the school principal adopts an instructional approach, he/she is expected to provide resources for teacher learning, create a culture of teacher collaboration whereby teachers mindfully share the success and challenges of instructional strategies that may have been successful or ineffective (Wallace Foundation, 2006). Furthermore, while principals are supposed to challenge ineffective practices, challenging a long-standing culture within a complex system of the school is difficult (Fullan, 2001). However, researchers (e.g., Elmore, 2002; Kmetz & Willower, 1982) highlighted that principals' daily routine is primarily consumed with managerial tasks,

and they do not have time to focus directly on the improvement of curriculum and instruction. As a result, there was a shift in leadership style from the mid-1980's to present toward a decentralization of power between the principal and teachers for what is called distributed leadership (e.g., Elmore, 2000; Gronn, 2000; Halverson et al., 2011; Hardy, 2010; Leithwood & Jantzi, 2000; Smylie, Conley, & Marks, 2002; Spillane, Halverson, & Diamond, 2001; Wallace, 2002). Although leadership from the school principal is a crucial factor for professional learning and to facilitate the knowledge growth of teachers in a constructivist manner (Colantonio, 2005), leadership stemming from the teachers is equally crucial (Leithwood, Harris, & Hopkins, 2008). Fullan (2007) found that teachers with little support from administrators, and who have little input into decision making, are more likely to leave the teaching profession or change schools. The implementation of distributed leadership fosters school improvement efforts (Hord, 1997; Hord & Sommers, 2008) by delegating responsibilities to help teachers assume responsibility for their learning and their colleagues (Lindstrom & Speck, 2004). It must also be noted that although teachers can initiate their involvement in professional learning to improve their teaching, “without coordinated organizational support [from school leaders], teacher initiatives can be pushed to the margins of the school instructional program” (Halverson et al., 2011, p. 410). In this capacity, implementing science reform strategies such as professional learning requires both the formal leadership of principals, and the informal leadership from school teachers, otherwise known as “*de facto* instructional leaders” (Halverson et al., 2011).

With great responsibility and leadership comes hardship. First, leaders can undermine or neutralize reform efforts. Reasons can include there being a lack of leadership will and skill (Halverson et al., 2011), or, leadership practices have been shaped by pre-existing structures, priorities, and decisions about the organization of teaching and learning. As a result, leaders are functioning within pre-existing and complex systems of practice (Halverson, 2003), and some components of their practice are beyond their capacity to change (Halverson, 2011). Secondly, Mullen and Hutingger (2008) explain that principals face substantial challenges when teachers are unable to collegially and collectively work together. Conflict amongst teachers can stem from tensions in disengagement, disinterest, or resistance, and conflicting duties. Principals can

help snub these issues by promoting teacher-led, non-mandated initiatives; from keeping members focused on the vision and goals of purposeful study groups; and from allocating resources effectively and wisely (Hutinger & Mullen, 2007) and by holding teachers accountable for their decisions and use of time. Also, principals can foster ways to build the school milieu so that it has positive synergy: enabling individuals to satisfy both personal and shared goals, encourage members to expose personal shortcomings, experiment with unfamiliar teaching techniques, and challenge their philosophical constructs (Mullen & Hutinger, 2008).

Leadership of school principals in Ontario, Canada. According to the Ontario Leadership Framework (2013), the Ontario ministry developed Core Leadership Capacities to help teachers meet provincial educational goals through professional development. The components of the Core Leadership Capacities include: (1) setting goals and making sure they are strategic, specific, measurable, attainable, results-oriented, and time-bound so that they lead to improved teaching and learning; (2) aligning resources (e.g., financial, capital, human resources, curriculum, professional learning resources) with priorities with a focus on student achievement and well-being; (3) promoting collaborative learning cultures within and between school to focus on improved teaching quality and student achievement and well-being; (4) using data to identify student strengths and weaknesses to tailor teaching actions; and (5) engaging in courageous conversations for teachers to foster innovation and feedback that will lead to improvements in student achievement and well-being. In addition, in the report titled, *Ontario District Embraces an Evolving Approach to Learning*, by Belchetz and Witherow (2014), leadership is an essential component of “engaging teachers in learning in their local settings is essential – it is no longer enough to have a few innovators implementing new practices in isolation” (p. 22). Every teacher needs to be actively engaged in professional learning, but for that to happen, district and school leaders need to be able to integrate collaborative professional learning opportunities into regular teaching practice rather than considered them as “add-ons” to teacher workload (Belchetz & Witherow, 2014). Thus, principals need to consider teacher professional learning to promote teacher development and school-based change (Capobianco, 2007; Pithouse, Mitchell, & Weber, 2009; Scharmann, 2007). The Ontario Ministry of Education, 2007

revised curriculum for science and technology also states that school principals are responsible for promoting teachers “learning teams” and to assist teachers in their participation in professional learning.

Additionally, the Ontario Ministry of Education supports teacher professional learning, but with a strong political agenda. Principals need to maximize student performance on standardized tests, particularly in numeracy and literacy, and the use of data collected from summative and formative assessments to guide teachers to better teach to the learning needs of students (Hardy, 2010). Noted is the lack of drive for improving science in Ontario. Halverson and colleagues (Halverson et al., 2011) pointed to the fact that as the local leaders “gauge competing pressures to improve different areas of the instructional program, science reform seldom emerges as the top priority (even as international comparisons push science as a national priority)” (p. 412-413). This is a reason for the lack of congruency between principals push for strong reform-based practice regarding science and the need to improve student achievement in science. Reform efforts have been worked to reshape mathematics and language arts instruction in response to the standardized tests, and schools have increased the allocated teaching time for mathematics and literacy instruction but have reduced the resources available for science (Halverson et al., 2011). Principals are torn between the bureaucratic agenda of ensuring their school successfully responds to the “generic conceptions of educational improvement” (Hardy, 2010, p. 432) and the specific needs of the students situated in the local context of their school (Hardy, 2010). Consequentially, in a time of high-stake, standardized testing for numeracy and literacy and considering that elementary teachers are typically generalists, principal leadership and their scaffolding ability is key to improving teacher instructional strategies, and content and theoretical knowledge about science (Halverson et al., 2011). Teachers can learn from the school leaders, or science coaches provided by the school leader, within a learning community that fosters teacher growth in learning and teaching science (Halverson et al., 2011). However, professional learning can be viewed as a top-down, mandated activity (Day & Sachs, 2004) that is also “individualistic, short-term and decontextualized activities often in response to bureaucratic or administrative fiat” (Hardy, 2010, p. 72).

Teacher Beliefs. Teacher beliefs are at the “very heart of teaching” (Kagan, 1992, p. 85). The current research adopts Southerland, Sinatra, and Mathews (2001) interpretation of the distinction between beliefs and knowledge because their work is embedded in science education research and teaching. Both are rooted in experience; however, knowledge is primarily a cognitive structure, while beliefs include cognitive and affective components. Considering that beliefs are rooted in affective components, they are recognized as subjective, personal, and reflective of individual judgment (Lundeberg & Levin, 2003; Richardson, 2003), and they behave like a filter for interpreting and addressing daily experiences and actions (Fives & Buehl, 2012). Overall, beliefs are important to consider because they provide a means for interpreting the “underlying psychological constructs and conceptual representations that guide teacher decision making and instructional practices” (Hoffman & Seidel, 2015, p. 118).

Topics about beliefs and their relation to science education include, but are not limited to: classroom practice for science (Haney, Lumpe, Czemiak, & Egan, 2002; Jones & Carter, 2007; Wallace & Kang, 2004); whether teachers will embrace student-centered, inquiry-based instruction inquiry science teaching (e.g., Breslyn & McGinnis, 2011; Choi & Ramsey, 2009; Crawford, 2007; Saad & BouJaoude, 2012; Smith & Southerland, 2007) and reform-based practice (Roehrig & Kruse, 2005); the nature of science knowledge (Kang & Wallance, 2004; Tsai, 2006) and goals for teaching and learning science (Friedrichsen, van Driel, & Abell, 2011); student learning (Crawford, 2007); and engagement in professional development (Lumpe, Czerniak, Haney, & Beltyukova, 2012). Also, beliefs about science knowledge influences curriculum decisions (Stolberg, 2007), which can then influence student notions about the nature of science (Longbardi & Sinatra, 2013).

Educational researchers have studied beliefs in general as a means to modifying teaching practice toward student-centered instruction. From the perspective of Buehl and Beck (2015), there is a “reciprocal, but complex, relationship between teachers’ beliefs and practice” (p. 70), and teacher beliefs help to better understand their practice (e.g., Ball, 2009; Ingvarson, Meiers, & Beavis, 2005). Beliefs are also highly contextualized (Mansour, 2009, 2013) and may influence whether beliefs are static or change over the course of a teacher’s career. Research has shown that the development of beliefs is

influenced by the social, cultural, political and historical context that teachers engage in daily (e.g., Beijaard, Meijer, & Verloop, 2004; Fairbanks et al., 2010). Thus, when addressing teacher beliefs, they cannot be separated from the context in which they occur because they are situational (Fives & Buehl, 2012; Chant, 2002, 2009; Levin, He, & Allen, 2013; Muis, 2004), and they are developed through collaborative interactions amongst fellow teachers, administrators, and other school personnel within the environment they are applied (Tschannen-Moran, Salloum, & Goddard, 2015). In 2009, Buehl and Fives identified six internal and external sources to the development of teacher beliefs, which are also agreed upon by other researchers (e.g., Levin & He, 2008; Levin, He, & Allen, 2010, 2013): formal education; formal bodies of knowledge; observational learning; collaboration; personal teaching experiences; and self-reflection. Considering that both internal and external factors influence teacher beliefs, working to change teacher beliefs alone to student-centered approaches may not be sufficient. Teacher beliefs need to be investigated within the context they are being applied (Fives, Lacatena, & Gerard, 2015) to understand the degree to which internal and external factors either support or hinder the relation between teaching beliefs and instructional strategies implemented in the classroom (Buehl & Beck, 2015). Jones and Leagon (2014) pointed out that a purpose of investigating teacher beliefs for science education is that:

teachers face a constantly changing landscape of standards, assessments, and curricula, and the beliefs and attitudes they hold shape the way they interpret and respond to changes and challenges. Science teacher beliefs and attitudes influence the interpretations of the curriculum, whether or not teachers use inquiry in their instruction, choices of assessments, and involvement in professional development. (p. 830)

Researchers (e.g., Osborne & Dillon, 2008; Rosenfeld & Rosenfeld, 2008) have claimed that the aim for teacher professional learning should be to improve teacher beliefs about science and science teaching. In this case, professional learning becomes critical considering the multitude of factors involved in the implementation of beliefs, and that when teacher beliefs do not align with their practice, it can affect teacher well-being and satisfaction (e.g., deJong, 2008; Potari & Georgiadou-Kabouridis, 2009).

When studying teacher beliefs and the literature on the related topic, cautions must be taking into account. Levin (2015) pointed out weaknesses about studies of belief

development: (a) the proliferation of terms describing teacher beliefs makes it hard to compare results because not all studies clarify what type of beliefs are studied, (b) the various contexts in which beliefs are studied such as participants with wide ranges of teaching experience, limits the full understanding of teacher beliefs and how they developed, and (c) most studies focusing on teacher beliefs are small case studies (one to four teachers). So there is a lack of generalizability and threat to validity. Considering that “researchers have seen the role that context and different domains of knowledge play in defining and understanding beliefs, they recognize the importance of being explicit about naming specific types of beliefs being studied” (Levin, 2015, p. 59). Therefore, in this research study, the beliefs being studied include two most widely discussed beliefs in science education, teacher epistemological beliefs, and self-efficacy (Chen et al., 2015), as well as teacher pedagogical discontentment.

Epistemological Beliefs. Lederman (2007) identified the nature of science as the “way of knowing, or the values and beliefs inherent to scientific knowledge and its development” (p. 833). Similarly, Olafson, Schraw, and Veldt’s (2010) definition of epistemological beliefs, is a “*set of beliefs* that collectively define one’s attitudes about the nature and acquisition of knowledge” (p. 244). Hofer and Pintrich (1997) also added that teachers can hold multiple beliefs that exist simultaneously. For instance, teachers may believe that scientific knowledge stems from professional scientists, yet there are multiple “right answers” to complex science problems.

There are two main conceptualizations about epistemological beliefs about teaching: student-centered approaches underpinned by constructivist views and secondly, teacher-centered approaches underpinned by a transmissionist approach (e.g., Gill & Hoffman, 2009; Richards & Gipe, 1994). Hodson (2009) highlighted that teachers who hold traditional views of science as fixed knowledge do not understand the need to teach about the nature of science. Although there are dichotomized perspectives regarding teaching beliefs, some researchers (e.g, Alger, 2009; Chant, 2002, 2009; Chant, Heafner, & Bennett, 2004; Fives & Buehl, 2008; Levin et al., 2010, 2013; Luft & Roehrig, 2007) claim that beliefs change over the course of a teaching career, or can change slowly but not easily (Schraw & Olafson, 2002), while others (e.g., Buehl & Beck, 2015) think that beliefs are more than less, stable constructs.

Implementing epistemological beliefs in teaching practice has shown to be complex because epistemological beliefs and practice may be misaligned (e.g., Olafson & Schraw, 2006; Lee, 2009; Liu, 2011; Niyozov, 2009) for reasons that include beliefs being influenced by changes in the political landscape (Fairbanks et al., 2010; Levin et al., 2010, 2013) and whether teachers think certain epistemological beliefs can be effective within their professional context (Fives et al., 2015). The notion of misalignment between epistemological beliefs and practice was acknowledged as far back as in 1988 by Cobb, Yackel, and Wood who noted that even though applying constructivist teaching pedagogy is beneficial, “deep-rooted” issues may arise when it is put into practice because teaching with constructivist beliefs is drastically different than teaching with traditional, positivist beliefs, and it is difficult for teachers to visualize and make the transition. Fives et al. (2015) highlight that although teachers can hold “desirable” beliefs that align with the student-centered approach to teaching and learning, they may not think that they can implement the desirable beliefs within their school context. Tsai (2006) found that science educators who hold simplistic epistemic beliefs tend to focus more on traditional teaching practices and teachers who hold constructivist beliefs engage their students in more inquiry-based investigations. Although Kang and Wallace (2004) also found that teachers with simplistic beliefs about science taught with more teacher-centered practices, they also found that teachers who hold constructivist beliefs were less consistent with implementing constructivist practices in science. Mansour (2013) found similar results to Kang and Wallace (2004). Also, Lim and Chai (2008) conducted a study with six teachers who were using computer-mediated lessons in subjects including science. They found that although five of the six teachers held constructivist orientations to teaching, the lessons that the researchers observed were primarily lecture based with only 80% of the lessons incorporating few constructivist elements.

Although researchers have identified a mismatch in beliefs and practice, other researchers (e.g., Bråten & Strømsø, 2004, 2005; Chen & Pajares, 2010) believe that when teachers hold either traditional or reform-based conceptions of science, they will orient their teaching toward their held conception so that students learn science in such a manner. Related to science education, researchers (e.g., Luft & Roehrig, 2007) suggested

that as teachers become more experienced in the profession, their teaching may become more student-centered from the shift in their epistemological beliefs.

Self-efficacy. Teacher self-efficacy has become a “significant predictor of teacher behavior that influences instructional practice, motivation, the effectiveness of professional development and the success of educational reform” (Jones & Leagon, 2014, p. 833). In 1997, Bandura explained self-efficacy to be the “beliefs in one’s capabilities to organize and execute the courses of action required to produce given attainments” (p. 3). The concept of efficacy was described by Bandura (1993) as a future-oriented construct – it guides future scenarios. The second component of Bandura’s concept of self-efficacy was outcome expectancy: “a person’s estimate that a given behavior will lead to certain outcomes” (Bandura, 1977, p. 79). Regardless of the research supporting a relationship between teacher efficacy, teacher outcome expectancy, and growth in student achievement (e.g., Angle & Moseley, 2009; Bruce, Esmonde, Ross, Dookie, & Beatty, 2010), self-efficacy and outcome expectancy bear little or no empirical relationship with each other, and self-efficacy is a much stronger predictor of behavior than outcome expectancy (Bandura, 1997). For these reasons, the concept of outcome expectancy will not be further discussed.

In general, teachers who are more self-efficacious “reflect on their experiences more adaptively, plan and organize more effectively, are more likely to employ and seek out engaging instructional strategies, put forth greater effort in motivating their students, and are more resilient when faced by obstacles” (Chen et al., 2015, p. 372). However, self-efficacy has been debated as a domain-specific affective response that is context sensitive. For instance, Tschannen-Moran, Woolfolk Hoy, and Hoy (1998) expressed that teaching self-efficacy “has been defined as both context and subject-matter specific. A teacher may feel very competent in one area of study or when working with one kind of student and feel less able in other subjects or with different students” (p. 215). Thus, the four sources that Bandura (1997) described as informing self-efficacy are developed in context and pertaining to specific subject matter. For the purpose of this research, each source is briefly discussed regarding science education. One source is called *vicarious experiences*. Bandura (1997) explained that when teachers envision themselves mastering a challenging task, it will help improve their self-efficacy. Primary teachers can envision

themselves completing tasks by watching others successfully complete scientific endeavours on science television programs and then having an increased science teaching self-efficacy (Mansfield & Woods-McConney, 2012). A second source is called *social persuasions*. Information such as feedback that teachers receive can greatly influence their science teaching self-efficacy. For instance, Palmer (2011) found that the feedback elementary teachers received from an observer after engaging in professional learning programs was the greatest impact on their science teaching self-efficacy. A third source is called *Psychological and affective states*, which may influence self-efficacy judgments of capability with respect to specific tasks. For instance, emotional reactions such as anxiety can lead to negative judgments about the ability to successfully teach science. However, “the relationship between psychological and affective states to teachers’ beliefs about their ability to teach science is unclear” (Chen et al., 2015, p. 377). The fourth source identified as helping to develop self-efficacy comes from *mastery experiences*. Mastery experiences occur when someone performs a task for themselves. This provides the most authentic confirmation that the person in question can succeed. On the other hand, failing to deal with a task can undermine one’s self-efficacy (Bandura, 1997). “Research on science teaching self-efficacy has focused most on the influence of *mastery experiences*, perhaps because Bandura argued that such experiences typically had the greatest effect on self-efficacy” (Chen et al., 2015, p. 375).

A means for teachers to develop mastery experiences is to engage in collaborative professional learning. Jones and Leagon (2014) stated that the most recent and influential study in the past five years related to self-efficacy and professional learning programs was conducted by Lumpe et al. (2012) and then Lakshmanan, Heath, Perlmutter, and Elder, (2011). Their research found that teachers’ self-efficacy greatly increased upon their participation in an intensive professional development program that provided them with content knowledge, teaching strategies, and the ability to apply their knowledge in authentic contexts. Lakshmanan et al. (2011) added that these findings occurred when teachers engage in professional learning activities for an extended period of time with the assistance of coaches and mentors. Here, teachers gain a deep understanding of content knowledge which results in their increased self-efficacy to teach science. Similarly, researchers found that the more time elementary teachers spent on content knowledge

about science in professional learning activities, the more self-efficacious they were as science teachers (e.g., Sandholtz & Ringstaff, 2011; Sinclair, Naizer, & Ledbetter, 2011), and when teachers have inadequate science knowledge, it may contribute to having lower self-efficacy to teach science (Swars & Dooley, 2010). In addition, researchers (Lakshmanan et al., 2011; Posnanski, 2002; Sandholtz & Ringstaff, 2011) found that when elementary science teachers participated in professional development programs for an extended period of time, not only did their science self-efficacy increase, so did the amount of time they spend teaching science and their use of inquiry-based instructional methods. Teachers with high science self-efficacy are more likely to apply student-centered practices (Ramey-Gassert, Shroyer, & Staver, 1996). For instance, evidence suggests that in-service teachers with higher levels of science teaching self-efficacy: (a) claim to ask more open-ended questions (Riggs, Enochs, & Posnanski, 1998); (b) do a better job of connecting science content to student lives and/or the real world (Haney et al., 2002; Riggs et al., 1998); (c) teach more science per week (Desouza, Boone, & Yilmaz, 2004); (d) report using more hands-on activities (Marshall, Horton, Igo, & Switzer, 2009); (e) incorporate more inquiry-based activities (Haney et al., 2002; Lakshmanan et al., 2011; Nolan et al., 2011); and (f) present scientific content that is more accurate (Haney et al., 2002). On the contrary, researchers have demonstrated that elementary teachers with low science efficacy are more likely to result in the use of teacher-centered science instruction (Riggs & Enochs, 1990). However, it is important to note that studies have not shown that teacher's science self-efficacy was the variable that mediated the relationship between engaging professional development activities and teacher behaviour. More research is necessary to determine the causal links between teacher's science self-efficacy, inquiry-based teaching and professional development (Chen et al., 2015).

Collective efficacy. Along with individual teacher self-efficacy is the construct of collective efficacy: "a group's shared belief in its conjoint capabilities to organize and execute courses of action required to produce given levels of attainment" (Bandura, 1997, p. 477). Collective efficacy results from the dynamics between group members (Goddard, Hoy, & Woolfolk Hoy, 2000) and is more so related to school outcomes rather than individual teacher self-efficacy (Goddard & LoGerfo, 2007). Also, collective efficacy is

not the sum of individual teacher self-efficacy (Bandura, 1997); it is the beliefs of what teachers can accomplish as a group. However, individual self-efficacy and collective efficacy are reciprocal and influence one another (Goddard & Goddard, 2001). Collective efficacy is important to consider because schools are organizations where teachers and administrators work together to influence student achievement while collectively working with accountability measures put forth by policymakers (Elmore, 2007). Thus, the shared attitudes of teachers are an important characteristic within a complex school environment (Tschannen-Moran et al., 2015). Collective efficacy beliefs influence student achievement by influencing teacher persistence with students who are struggling and how much effort teachers invest in planning their instruction (Bandura, 1993, 1997; Goddard et al., 2000). Secondly, collective efficacy beliefs influence the degree to which teachers collaborate. For instance, teachers with high self-efficacy but low collective efficacy may be isolated from fellow teachers for constantly trying to improve student achievement. On the other hand, teachers with low self-efficacy working in a school with high collective efficacy may become more motivated to improve their teaching. Also, schools with teachers who share high levels of collective efficacy foster collaboration to improve their instructional strategies and are more resilient to challenges (Goddard, Goodard, Kim, & Miller, 2011). Thus, Goddard et al. (2011) and Moolenaar, Slegers, and Daly (2012) expressed that promoting teacher collaboration to focus on improving instructional strategies is a means to improve collective efficacy.

Interplay between teacher beliefs and collaborative professional learning. Chen et al. (2015) adopted Molden and Dweck's (2006) idea that individual variables are not the sole contributor to behavior (see Chen et al., 2015, figure 21.1, p. 379): self-efficacy acts as a mediator between which teaching strategies are applied in the classroom (Dweck & Leggett, 1988). For instance, Chen et al. (2015) explained:

If teachers see science as mostly a collection of simple absolute truths, they may be more inclined to see their goal as getting their students to recall and demonstrate their scientific knowledge on tests. And if teachers are confident in their abilities to engage students and teach them these scientific truths (i.e., possess high science teaching self-efficacy), they are more likely to do an effective job at preparing students to perform well on these tests. Low teaching self-efficacy, however, is likely to result in effective teaching of the science canon. On the other hand, if teachers see science mostly as a dynamic and evolving body of knowledge, they may be more likely to see their goal as

providing students with opportunities to understand and appreciate the complexity of scientific concepts. Furthermore, if teachers believe that they are equipped with the necessary knowledge and skills to engage and teach students these dynamic scientific concepts, teachers are more apt to engage their students in more complex science activities that allow students to grapple with this complexity. However, if teachers lack the self-efficacy to engage students and teach them the dynamic and evolving nature of science, they are more likely to see their job mostly as depositing pieces of knowledge into students' minds. (p. 380)

It is also important to remember that teacher's self-efficacy to engage students in inquiry-based activities is informed by the context: the relationship between beliefs and practice includes internal and external contextual factors. Kang and Wallace (2004) expressed that institutional factors such as resources or teaching to the test reduced teacher self-efficacy to teach science. And, personal factors such as classroom management skills contribute to the degree to which teachers implement constructivist instructional strategies (Chen et al. 2015). Two well-known models developed by Guskey, and Opfer and colleagues were developed to highlight how professional learning can influence beliefs, which then lead to changes in instructional practice. First, Guskey (2002) has written extensively on how professional learning activities intersect with teacher attitudes and beliefs. He proposes that teacher attitudes and beliefs are changed through a sequential process beginning with professional development. Guskey's rationale is that once teachers have changed their classroom practice, and have evidence of student improvement, they alter their attitudes and beliefs. Therefore, changes in student learning is a prerequisite for changing teacher attitudes and beliefs. Secondly, Opfer, Pedder, and Lavicza, (2010) provide a model of teacher learning whereby the change of teachers' beliefs, practice, and professional learning is a "reciprocally causative" as opposed to linear in Guskey's (2002) model. Note that van Aalderen-Smeets and van der Molen (2015) said that "even within studies, the relation between increased skills and knowledge on the one hand and attitudes on the other remains unclear" (p. 712).

It is critical to address teacher beliefs with reform-based science education because of teacher resistance to reform-based practices (e.g., Ambrose, 2004; Bray, 2011; Ertmer & Ottenbreit-Leftwich, 2010; Windschitl & Sahle, 2002). Thus, teacher professional learning within the school environment is utmost important to understanding

the interplay between beliefs and practice within a complex and multifaceted school environment. The importance of highlighting teacher beliefs and the role of professional learning is that understanding teacher beliefs can provide an understanding of how to better support teacher professional learning throughout their career (Chant, 2002, 2009; Levin, 2015; Levin et al., 2010, 2013), as well as how professional learning within the school can help tailor teacher beliefs. Chen et al. (2015) explained that providing teachers with training, resources, and personalized feedback within their working context may be the most effective way to generate changes to teacher practice and beliefs about science education. However, a known drawback to effective collaborative professional learning “is the failure to address teachers’ attitudes and beliefs about their instructional practices. Providing teachers with new models of instruction or a new curriculum without addressing the underlying belief systems can lead to little meaningful change” (Jones & Leagon, 2014, p. 830).

Pedagogical discontentment. Another facet to teachers’ affective state that has been identified as a catalyst to change teachers practice is a theoretical construct of pedagogical discontentment. Pedagogical discontentment has been defined as “teacher’s affective response to the evaluation of the effectiveness of existing science teaching practices and goals” (Southerland, Sowell, Blanchard, & Granger, 2011a, p. 304), and “the unease of ones experiences when the results of teaching actions fail to meet with teaching goals” (Southerland, Sowell, & Enderle, 2011b, p. 439). The term *pedagogical discontentment* was adopted from Feldman (2000) who used the term to describe the discrepancy between teacher goals, instructional practices, teaching beliefs and student learning outcomes (Gess-Newsome, Johnston, & Woodbury, 2003). Feldman (2000) argues that authentic change in understanding takes place when teachers “are discontent with their old practical theories and they find the new ones sensible, beneficial, and enlightening” (p. 613). Southerland et al. (2012) state that there have been a few studies (e.g., Feldman, 2000; Gregoire, 2003) that recognized the dissatisfaction teachers have with their teaching as an important factor contributing to teachers changing and improving their teaching practice. With regards to collaborative professional learning and science education, Saka, Southerland, and Golden (2009a) highlighted that to understand why teachers would participate in collaborative professional learning activities to further

their teaching knowledge and instructional repertoire, it is important to have an understanding of their dissatisfaction with their current practice, and why they would consider such transformation to adopt reform-based practice. Southerland et al. (2012) also noted researchers (e.g., Feldman, 2000; Sarason, 1982; Southerland et al., 2011a; Smith, 2005; Sunal et al., 2001; Woodbury & Gess-Newsome, 2002) who claimed that teachers teaching science must be dissatisfied with their current ideas of teaching science before engaging in transforming their practice because the feeling of dissatisfaction with their teaching practice gives them the motivation to engage in new, beneficial, and enlightening reform teaching.

There is growing empirical support, qualitatively (Saka, Southerland, & Brooks, 2009b) and quantitatively (Blanchard & Grable 2009; Golden, Enderle, & Southerland, 2010, Golden, Southerland, & Saka, 2009; Sowell, Southerland & Granger, 2006), that pedagogical discontentment is predictive of gains in teachers use of reform-based teaching practices as a result of their participation in collaborative professional learning. For instance, Blanchard and Grable (2009) and Golden et al. (2010) found that teachers (including those who taught science) who were more pedagogically discontent applied more reform-based teaching strategies in their teaching practice after engaging in professional learning activities. Thus, researchers (e.g., Sowell et al., 2006; Southerland et al., 2012) suggest focusing on teacher pedagogical discontentment with their current practices, and the degree of engagement with existing reform-based education to understand the manner in which teachers enact or reject reform. For instance, Smith (2005) and Feldman (2000) suggested that teachers who were not discontent and more so content with their teaching practice would have minimal motivation to modify and shift their teaching practice toward inquiry-based teaching. On the other hand, if teachers feel discontent with their current practice, they are more open and receptive to changing and revising their teaching practice.

Researchers have investigated pedagogical discontentment by using a measure created by Southerland, Sowell, Kahveci, Granger, and Saka (2007) called, *Science Teachers' Pedagogical Discontentment scale* (STPD). Based on Golden et al.'s (2009) quantitative study examining the effects of professional learning, 24 experienced elementary and high school teachers with a strong sense of discontentment (measured by

the STPD) were more likely to enroll in professional learning activities that focused on supporting changes in teaching practice. Golden et al. (2009) described pedagogical discontentment as predictive of teacher's use of inquiry-based teaching as a result of professional development. More recently, the STPD was used by Saka (2013) in their mixed methods research to study the kind of elementary, middle and high school teacher that applies for a particular professional learning program during the summer. Their findings suggested that teachers who were more pedagogically discontent enrolled in a program that was focused on providing them with inquiry-based teaching tools as opposed to programs providing authentic science experiences.

Relationship between pedagogical discontentment and self-efficacy. Relationships have been identified between teacher pedagogical discontentment and self-efficacy (Saka, Golden, & Southerland, 2009c) and between pedagogical discontentment, self-efficacy, and teaching practice to understand teacher openness to reform-based practice (Southerland et al., 2011a). First, the predominant difference between teacher pedagogical discontentment and self-efficacy is that the first describes current assessment of teaching whereas the latter describes future teaching practices (Southerland et al., 2011b). Teachers' reflection on their current practice (pedagogical discontentment) compared to their future capabilities (self-efficacy) can develop a sense of pedagogical discontentment and create the motivation for greater engagement in reform-based teaching practice and/or to engage in reform-based professional learning to change their teaching practice (Southerland et al., 2011a/b; Southerland et al., 2012).

Researchers (Sowell et al., 2006; Southerland et al., 2007; Saka et al., 2009c) suggest that a teacher with a combination of pedagogical discontentment and high self-efficacy may be more receptive to reform initiatives within professional learning activities. Meanwhile, Saka et al. (2009a) examined the interplay of pedagogical discontentment, self-efficacy, and novice science teacher's adoption of reform-minded practices. Their qualitative, 2-year study found a high degree of pedagogical discontentment combined with a moderate level of self-efficacy was necessary for the enactment of reform-based teaching practice. Then, Southerland and colleagues (2011a) created a model describing the relationships between pedagogical discontentment and self-efficacy, and how their relationship can translate into teachers' openness to

participating in professional learning activities. The model (Figure 1) provides a rationale as to why teachers with varying degrees of self-efficacy and pedagogical discontentment may or may not resist change to their teaching practice. Thus, pedagogical discontentment is an important construct to measure because there are benefits of researching “both self-efficacy *and* pedagogical discontentment when one attempts to understand teachers’ resistance or openness to change” (Southerland et al., 2011a, p. 301).

	<i>High Self Efficacy</i>	<i>Low Self Efficacy</i>
<i>Pedagogical Contentment</i>	<i>No changes</i>	<i>No changes</i>
<i>Pedagogical Discontentment</i>	<i>Changes</i>	<i>Possible changes</i>

Figure 1. Model of Teacher Self-efficacy, Contentment, and Anticipated Changes in Practice. The relationships between pedagogical discontentment and self-efficacy, and how this translates into teachers’ openness to professional development activities. Adapted from “Exploring the Construct of Pedagogical Discontentment: A Tool to Understand Science Teachers’ Openness to Reform” by S. Southerland, S. Sowell, M. Blanchard, and E.M Granger, 2011, *Research in Science Education*, 41 p. 307. Copyright 2010 by Springer Science and Business Media.

Chapter Summary

This chapter has provided an overview of the research literature regarding teacher engagement in collaborative professional learning and related constructs. In particular, there are three important themes that emerged from this literature review:

Section 1: The Current State of Elementary Science Education and Teachers Classroom Practice

- The development of students' understanding and appreciation of science begins with teachers. So, teachers must have a comprehensive understanding of scientific knowledge and how to teach science using an inquiry approach. Meaning, teachers need to be able to develop a student-centered learning environment that encourages students to think about questions, seek answers to those questions, experience the phenomena, share ideas, and develop explanations of science concepts based on evidence. However, research shows that teachers are largely using teacher-centered pedagogical approaches that do not align with the inquiry approach.

Section 2: Collaborative Professional Learning for Science Education

- Ongoing and effective collaborative professional learning related to science offers teachers a platform to engage with one another for the sake of improving their science content knowledge, instructional strategies, and to develop student-centered beliefs. Ultimately, teacher engagement in collaborative professional learning helps to improve student achievement in science.

Section 3: External and Internal Contextual Factors Influencing Teacher Engagement in Collaborative Professional Learning for Science Education

- Principal leadership ranks second beside classroom instruction amongst all potential factors contributing to student learning at school. Principals have the role to provide opportunities for teacher learning in science, yet meet accountability demands from the Ministry of Education that are primarily focused on literacy and numeracy.
- Teacher beliefs (epistemological belief, self-efficacy, and pedagogical discontentment) influence the instructional strategies implemented in the classroom and whether teachers choose to engage in collaborative professional learning to modify their practice toward a student-centered inquiry approach. Teacher beliefs are contextual and thus, need to be investigated in the school of practice, amongst their daily activities.

CHAPTER III: THEORETICAL FRAMEWORK

Situated Learning Theory as characterized by anthropologists, Lave and Wenger (1991) serves as the predominate theoretical approach framing this research study. Briefly, the concept of situated learning gained momentum in the field of education in the late 1980s and early 1990s (e.g., Brown, Collins, & Duguid, 1989; Cobb, 1994; Greeno, 1991; Lave, 1988; Lave & Wenger, 1991; Pea, 1989) as it provides a viewpoint on the nature of knowing and learning whereby learning is embedded in larger social, cultural, and physical arenas that can either afford or constrain knowledge development (Lave, 1988). Lave and Wenger (1991) stated: “learning is an integral part of generative social practice in the lived-in world” (p. 35) whereby learners routinely become engaged in a “culture of practice” (p. 95). In this capacity, situating teacher learning has the advantage of: (a) placing learning in the school setting and environment where socially acquired ways of knowing are often valued, (b) increasing the likelihood of the application of new understandings within similar contexts, and (c) strategically applying the learner’s prior knowledge on a given subject (Lave & Wenger, 1991). The two main reasons for applying situated learning to this research study were that viewing knowledge as situated has implications for understanding teacher learning and the design of instructional activities (McLellan, 1996). This aligns with the purpose of this research which is to illuminate elementary teachers and their school principal’s multiple and competing views about personal and contextual factors affecting teacher engagement in collaborative professional learning related to science education within the school environment.

Overview of Situated Learning as a Theoretical Approach

An issue emerging in the research literature about learning how to teach science education is *how* teachers are learning (Bishop & Denley, 2007) because the quality of teaching is key to student achievement (Hattie, 2008). Situated learning acts as a “transitory concept” or a “bridge” between cognition, language, teaming, agency, the social world, and their interrelations (Lave & Wenger, 1991) and considers the learning phenomenon from a broader and holistic standpoint by adopting the notion that learning is not limited to knowledge of facts or contextual influences per se. Knowledge arises conceptually (e.g., dynamically constructed, remembered, reinterpreted) and is produced through forms of “social co-participation” related to “actional contexts” instead of “self-

contained structures” (Lave & Wenger, 1991). Thus, to understand how teachers learn and the conditions for science teacher learning from a situated learning perspective, three conceptual themes are advised by Wallace (2003). First, learning needs to be situated and stemming from authentic activities. Other researchers also suggest learning is more effective when it is situated in authentic, real-world contexts (e.g., Lave & Wenger, 1991; National Research Council, 2007, 2012; Rivet & Krajcik, 2008; Roth, 2014; Sawyer, 2006) such as teachers navigating their professional learning through the daily situations that arise during school hours from parents, students, colleagues, administrators and the school culture (Lewis et al., 2015). Secondly, learning about science and learning to teach science needs to be a social activity to engage all learners and to create collaborative discourse about science education. Lastly, teacher learning is valuable when it is collaborative. Kelly (2014) also highlighted the increasingly recognized value of the social practice of learning and teaching science. Given this, the contexts formed by communities of teachers, administrators and other educators, along with available resources are critical as they can either afford or constrain what teachers learn about science (Sadler, 2009). Luft and Hewson (2014) add that professional learning related to science education requires outlining the content being discussed and learned, the process of the professional development program, and the context. The context includes school factors that influence the support teachers may receive to participate in learning communities from administrators and/or fellow teachers, and provincial and national policies that can articulate the need for science teachers to engage in professional learning to enhance their learning and teaching practice.

Philosophical Background of Situated Learning

Situated learning is aligned with the importance of teacher collaboration and collegiality for community-based learning and practice supported by sociocultural learning theories (Lave & Wenger, 1991). Concerning sociocultural learning theories falling under the board category of constructivism, researchers take the stance that the broad philosophical perspective of constructivism is a theory and a belief about *learning* (e.g., Fives et al., 2015; Richardson & Placier, 2001; Windschitl, 2002). Under this premise, learners are assumed to be active participants in the construction of their knowledge and that social interactions and contextual situations influence learning (see

Windschitl, 2002). Thus, teachers are not people who receive external information and teach curriculum; they are responsible for understanding subject context such as science for themselves, and creating instructional techniques that resonate with their students (Nova Scotia Department of Education & Early Childhood Development, 2011).

Implicit in the widespread attention given to situated learning is the recognition of a fundamental shift in learning about science and teaching science. Holding the belief and application of situated learning to education requires teachers to make an epistemological shift away from learning and teaching from a traditional point of view toward social constructivism. The shift entails disregarding the belief that knowledge is discrete, abstract, or objective, and it is simply transferred from one person to another or from teacher to student or from expert to novice. Rather, knowledge is developed amongst a group of individuals within a particular social and cultural context while engaged in an activity stimulating learning (Brown et al., 1989). Thus, this theoretical approach suggests that learning and knowing are not separate from the environment in which they occur and cannot be isolated events in the mind of individuals.

The idea of underpinning teacher collaborative learning with a sociocultural philosophy is not new in science education – particularly the idea that knowledge is constructed and not copied or transferred (Janssen & van Berkel, 2015). In 1916 Dewey expressed that the field of education needed to take a new avenue - toward participatory engagement in social practices. Dewey explained that challenges for teachers may not be only associated with acquiring new science pedagogical practices, but making personal sense of situated learning as a basis for instruction and reorienting their classroom practice be to consistent with the philosophy. Dewey conceptualized “situated” as specific circumstances of a context coupled with the individual’s cognitive construction of knowledge. In 1910, Dewey made the case that the teaching of science has suffered because science has been frequently presented as ready-made knowledge, facts and laws, rather than as an effective method of inquiry (Crawford, 2014). Then, in 1916, Dewey expressed that the field of education needed to shift toward participatory engagement in social practices (McLellan, 1996, p. 110). Following, Lev Vygotsky proposed that as “man is a socio-creature, that without social interactions he can never develop in himself any of the attributes and characteristics which have developed as a result of

methodological evolution of all humankind” (Vygotsky, 1994, p. 352). Given this, learning must be understood to be “the product of a collaborative construction of understanding” (Vygotsky as cited in Billett, 1994, p. 7). Thus, it was recognized more than 100 years ago that students need to learn more than facts and teachers need to adjust their science instruction to the method of inquiry. So attention is currently being focused on the nature of professional learning that is available to teachers and whether they are learning (Bishop & Denley, 2007).

Practicality of Situated Learning in Educational Contexts

Most recently, Janssen and van Berkel (2015) highlighted an important remark about constructivist and sociocultural learning theories related to science education:

[they are] too abstract, but also incomplete ... science teachers must make choices about *what* they should teach, *how* they should teach and *why* it is important to teach. Educational constructivism, however, does only make a statement about some aspects of the how but is largely silent on the what and the why. (p. 230)

The authors continue to state that the philosophy is too abstract to “guide teachers’ practical reasoning” (p. 229). Within a complex system bounded by time and resources, it is unclear for teachers how to translate philosophical suggestions such as social constructivism into concrete and practical tasks (Janssen & van Berkel, 2015). Teachers teaching science education need to know the practical information about what they should and will teach, and how and why they will teach a subject, topic, or investigation (Arnold, 2012). Therefore, it is important that:

these philosophies are developed into a heuristic model that will provide teachers the necessary guidance. This means that implications of these philosophies have to be elaborated on an intermediary level, that is, into a less abstract heuristic model that can function as a bridge between abstract philosophical ideas and specific teaching situations (Zeitz, 1997; Janssen et al., 2009). Given the limited time and resources of teachers, such a heuristic model enables them to plan and revise their daily lessons in terms of chosen abstract philosophies. (Janssen & van Berkel, 2015, p. 232)

Janssen and van Berkel’s (2015) statements about needing to implement a heuristic model that provides teachers with guidance to learn about science and to teach science under the conditions of the school environment aligns with other researchers describing practical models that outline how learning can occur (e.g., Brown et al., 1989; Lave &

Wenger, 1991) and researchers expressing the need for a “stronger theoretical base that reflects the complex ecology in which teachers work and learn” about science education (Wilson, 2013, p. 313). For example, Wilson (2013) identified teacher professional learning as one of the “grand challenges” in science education research and called for a more complex view of teacher learning; “one in which professional learning is seen as more dynamic and iterative, connecting teachers’ experiences in their classrooms with formal opportunities for collective reflection and for acquiring new knowledge that targets genuine problems of practice” (p. 311). Brown and colleagues (1989) discussed that teachers need to be aware of the distinction between the concepts presented in the curriculum and becoming familiar with the content of that knowledge, compared to acquiring the knowledge and being able to implement inquiry-based pedagogy in their teaching. Brown and colleagues discussed the distinction by addressing “knowing what” and “knowing how”. In terms of science education, without teachers knowing how to apply inquiry-driven processes using the concepts suggested in the science curriculum, the knowledge learned lies inert; ultimately, the students would only learn content knowledge without its application to real-life situations. In contrast, when teachers learn about content knowledge and how to apply it to real-life situations, they can better engage their students in the inquiry-driven process to gain content knowledge and an understanding of how to apply that knowledge to real-world situations. Although teachers regularly participate in professional learning that involves reform-based science practices, teachers struggle to change their teaching practice to implement practices that align with reform-based education, or inquiry-based pedagogy (Capps & Crawford, 2013; Gregoire, 2003). Moreover, money and time is being spent on professional learning to change science education, however, researchers have seen little evidence of changes to classroom practices. Woodbury and Gess-Newsome (2002) termed this, “change without difference”.

Given the dilemma about applying the theoretical construct to teaching practices, I have chosen to view this research through the lens of Lave and Wenger’s (1991) theory of situated learning in part because the authors address teacher learning within the context of the school through the interactions between educators to facilitate learning within a community of practice. In the quote below, Lave and Wenger (1991) explained:

Teachers are taught a skill in their workshops but they are not learning how to perform that skill within their daily practice so those skills may not transfer to teachers' practice even though they are aware of the concept. These "abstract representations are meaningless unless they can be made specific to the situation at hand [and] brought into play in specific circumstances." (pp. 33-34)

Thus, Lave and Wenger were also concerned about the ability of teachers to apply their learning to their practice. With the use of situated learning, teachers can understand the purpose or use of the knowledge they are acquiring because they learn by actively engaging in their knowledge development, rather than passively receiving the knowledge from an expert. Also, they learn various situations that their knowledge can be applied to, and eventually, teachers can abstract their learning to various situations, independent of context (Collins, Brown, & Newman, 1989). Below I discuss how teacher learning can occur within the context of the environment it is being applied.

Teachers-as-Learners in Communities of Practice

The report titled, *Professional learning cultures: An evaluation of collaborative inquiry in Ontario elementary schools*, by Bolden et al. (2014) centered its focus on teacher professional learning pointing to "teacher as learner" (p. 37) and "teacher as co-learner" (p. 45). For a teacher to be a learner, collaboration was the key factor influencing improvement to individual teachers practice, group practice, and the profession as a whole, as well as to provoke teacher reflection to further their learning. Thus, in Ontario, teacher learning by means of collaboration is being praised as teacher learning and/or learning to teach within the school environment whereby the social interactions and environment have the potential to foster meaningful teacher-to-teacher interactions. Other studies such as Geelan (1996) and Maor (1999), and programs such as the Project for the Enhancement of Effective Learning (Baird & Mitchell, 1986) described how positioning the teacher as the learner within a community helps guide teachers to reflect and deepen their science teaching, and adopt a social constructivist view of science education. Given this information about teacher-as-learner, the question becomes, how do teachers become learners through collaboration? Lave and Wenger (1991) describe this relationship within a Community of Practice amongst beginner and expert teachers whereby together, they negotiate meaning and construct understandings.

Community of Practice. In 1991, Lave and Wenger presented their model of situated learning and proposed that learning, which is central to situated learning theory, is a process of engagement in a *community of practice*. Later in 1998, Wenger further elaborated on the notion of Community of Practice (CoP) by describing it as “groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly” (Wenger-Trayner & Wenger-Trayner, 2015, p. 1). Wenger-Trayner and Wenger-Trayner (2015) outlined three characteristics that are required to develop a community of practice:

1. *The domain.* The community has a shared interest and are committed to a specific domain such as elementary science education.
2. *The community.* Members in the specific domain collaboratively interact in activities and discussions to share information and learn from one another. They simultaneously build trusting relationships that perpetuates their learning. Members do not necessarily interact daily but they do make time to interact.
3. *The practice.* Members of the community are practitioners. They develop and share resources, tools, stories, and knowledge to implement in practice. In this capacity, ongoing and sustained participation is required.

Various ways a Community of Practice engages in learning activities include: problem-solving, requests for information, seeking experience, building arguments, growing confidence, discussing developments and projects, observations, and mapping knowledge and identifying gaps (Wenger-Trayner & Wenger-Trayner, 2015).

Communities of Practice have come to the fore of educational research, including science education (Loughran, 2014). For instance, the development of the professional learning program, STaL (Science Teaching and Learning) that includes Communities of Practice, has shown to be effective in helping the development of teacher science learning and teaching (e.g., Daehler, Folsom, & Shinohara, 2011; Lindsay, 2006; Mitchell, 2002). Also, Akerson and colleagues (Akerson, Cullen, & Hanson, 2009) conducted a study with elementary teachers to understand their knowledge of, and practice of the nature of science. Their research findings suggested that teacher engagement in a Community of Practice within the professional learning program reinforced changes to the teachers science practice, and that the teachers became more eager to share stories about their

teaching. It was reported that “the CoP provided a supportive environment ... many teachers stated how much they appreciated the ideas generated by the group and how critical this support was in helping them grow as science teachers” (p. 1110). More recently, Loughran, Smith, and Berry (2011) found that a group of elementary school teachers teaching science developed a Community of Practice that “fundamentally changed” how they viewed science learning and teaching. Their group was based on the foundations of trust, respect, and listening to one another.

Learning and enculturation. Teachers become involved in a Community of Practice that embodies certain beliefs and behaviors to be acquired. The process of teachers becoming actively engaged in, and bringing their practice into a Community of Practice is called *enculturation* (Lave, 1988; Lave & Wenger, 1991). Members learn how to engage in a community by learning the cultural norms, tools, and operating procedures (Sadler, 2009). This learning process is not linear: as teachers engage in an activity, they learn about the cultural norms, and that leads to further participation and learning (Sadler, 2009). Enculturation is key to teacher learning because consciously or unconsciously, teachers adopt the behavior and belief systems of other teachers in the activity (Brown et al., 1989). As teachers engage in investigations for themselves, they pick up other’s jargon, behaviours, and eventually act accordingly, which then become the norms of the teachers involved in the learning activity (Brown et al., 1989). The aspect of enculturation is critical to teachers learning science via collaborative professional learning. The instillation of science teachers’ belief system about teaching with student-centered, inquiry-based pedagogy can only be achieved by teachers being enculturated in an environment that teachers actively take part in the practices themselves (Brown et al., 1989).

As teachers first begin the process of enculturation, they enter the Community of Practice as beginner learners, or as Lave and Wenger (1991) called a state of “legitimate peripheral participation”. Then they progress toward “full participation” as they become more active and engaged within the culture and assume the role of an expert teacher within the school milieu. The legitimate peripheral participation “denotes the particular mode of engagement of a learner who participates in the actual practice of an expert, but only to a limited degree and with limited responsibility for the ultimate product as a

whole” (Lave & Wenger, 1991, p. 14). The interactions involve the expert revising the “scaffolding for the learning as the novice’s capabilities develop, adjusting the support for the novice’s performance to a level just beyond that which the novice could independently manage” (Lave & Wenger, 1991, p. 116). This novice and expert categorization for knowledge acquisition is what Lave and Wenger (1991) believe to be a multi-level dialogue between a novice and more experienced colleague who share similar goals of improving student learning. This multi-level dialogue offers an avenue for beginner teachers to develop knowledge, skills, and identity by means of active participation as a way of learning. Beginners deconstruct and reconstruct their knowledge of practice as they routinely participate in learning activities from the periphery. The purpose of participating from the periphery “is not to learn *from* talk as a substitute for legitimate peripheral participation; it is to learn *to* talk as a key to legitimate peripheral participation” (Lave & Wenger, 1991, p. 109). Over time, knowledge is reconstructed and gained in the process of assuming an identity as a practitioner and becoming a full participant; thus, transforming from a beginner to an “oldtimer”. As a teacher becomes, and continues to be an expert teacher, according to Schon (1983), they hold a skill called “reflection in action” whereby the teacher can make decision in real time to successfully deal with unforeseen events. Hence, the teacher is able to address a situation by a student at the spur of the moment and allow students to improve their knowledge and skills. Lastly, with legitimate peripheral participation progressively becoming an oldtimer, there is not one avenue that must be taken, there are multiple ways to engage in the “complex, differentiated nature of communities” (Lave & Wenger, 1991, p. 36) because a single or center core of the community does not exist. The concept of levels discourse is similar to Vygotsky’s Marxist perspective of learning as decentered and within a Community of Practice.

Application of Situated Learning to my Research

In my research, I focused on understanding the nature of collaborative professional learning situated in an elementary school in Ontario to better understand affordances and constraints associated with teachers engaging in, and learning from, collaborative professional learning related to science education. The teachers were considered as learners and I investigated their interactions about how they were learning

about science, and learning to teach science education from their engagements in collaborative professional learning activities. Thus, the vision of my research problem coincides with Lave and Wenger's approach because it is grounded in the interactive and deeply adaptive learning from everyday experiences, thereby gaining knowledge from one another that would have otherwise been unavailable. As the theory of situated learning acknowledges that the brief, minor, or unassuming teacher-to-teacher interactions amongst a group of learners throughout the school day plays an important role in teachers learning, and learning to teach (Lave & Wenger, 1991), this research is investigating those day-to-day interactions with regards to science education. By addressing the social interaction between teachers and administrators, and by gathering monthly logs of teacher engagement in collaborative professional learning in real time, the theoretical approach within provides a lens as to how teachers within the school milieu actively and collectively co-construct knowledge to further their science teaching learning and teaching. Lastly, "a focus on the [interactions between study participants] as a unit of study frames the learning in terms of the social interactions and the communal support crucial to supporting learning and change" (Loughran, 2014, p. 817).

In line with situated learning, the focus of my research is on the culture of learning rather than the learning task (Rogoff, 1990; Wertsch, 1990). My research aligns with what James Greeno calls (1997) "the trajectory of participation" (p. 7) that can take place within the collaborative professional learning as teachers engage in a form of learning that is "personally and socially meaningful and [allows them] to foresee their participation in activities that matter beyond school" (p. 11). Also, the complexities of teaching are no longer viewed and expressed as a strict relationship between variables that are represented by statistical analyses (Aikenhead, 2006). They are viewed as an exploratory model such as teacher knowledge, educational worldviews and beliefs, and the contextual factor of the school milieu (Aikenhead, 2006). Thus, the situated learning approach endorses and guides my research within the school environment.

It is my assertion that applying situated learning as a theoretical approach can address three main concepts. First, it can help to understand the affordances and constraints associated with elementary teacher engagement in collaborative professional learning related to science education within the school environment. The theory of

learning provides me with a vision of how effective collaborative professional learning can be put into practice, therefore, providing the foundation to compare the theoretical perspective to current practice and address why collaborative professional learning activities and communities of teachers function the way they do, specifically about elementary science education. Secondly, the theoretical approach can help to unearth strategies that are useful for school administrators and the local school board as to how teachers situated and authentic science learning can be improved according to what is desirable from both teachers and their principal. Thirdly, the lense can help to conclude this research with a discussion about teacher engagement in collaborative professional learning within, and possibly out of the school environment, and how this engagement is influenced by social, cultural and contextual factors.

Chapter Summary

I primarily refer to Situated Learning Theory characterized by anthropologists, Lave and Wenger (1991). Situated learning has helped break the preconceived notion that teachers are independent learners. Rather, it stresses the importance of teachers being involved in Communities of Practice within a culture so that the learners can assist one another in the development of their understandings (Luft & Hewson, 2014). The first principle of the theory is putting 'learning-in-practice' (Lave, 1991). Knowledge needs to be presented in authentic, physical, and social contexts because learning is a co-constitutive process whereby all participants are transformed through their actions and relations. The second principle is that learning requires social interaction, participation, and collaboration. Cognition takes place within the world and not in minds construed separately from the world. Hence, learning should take place in complex, social situations. Lastly, cognition is distributed across people and tools (Putnam & Borko, 2000; Borko, 2004). It is situation-bound and distributed rather than decontextualized tools and product of minds (Lave, 1988).

CHAPTER IV: RESEARCH DESIGN, METHODOLOGY, AND METHODS

Research Design Overview

A qualitative case study design “has proven to be particularly useful for studying educational innovations” (Merriam, 1998, p. 41) possibly because the design allows for the investigation of “complex social units consisting of multiple variables of potential importance in understanding the phenomenon” (Merriam, 1998, p. 41). The case study design aligns with the purpose of this descriptive case study: to illuminate elementary teachers and their school principals’ multiple and competing views about personal and contextual factors affecting teacher engagement in collaborative professional learning (CPL) related to science education within the school environment. The descriptive nature of the study allowed for the emergence of the phenomenon’s multiple complexities and their interaction over a period of six months (Merriam, 1998) through reliance on thick descriptions. In this capacity, a descriptive qualitative case study provided a platform for the in-depth “discovery, insight and understanding” (Merriam, 1998, p. 1) of the phenomenon to be constructed from an inductive approach: allowing for themes related to teacher engagement in collaborative professional learning regarding science education to emerge from the perspective of elementary teachers and their school principal within the natural setting of the school environment. As Merriam (1998) argued, the design of case study research is generally emergent and flexible and is also grounded in a constructivist philosophical position (aligned with the theoretical framework, Situated Learning) that supported the dynamic interrelationship between this inquiry’s purpose, research questions, and methods. The following research questions provided a sound framework for this qualitative inquiry:

1. What are the perceptions of teachers and their school principal regarding collaborative professional learning related to science as a vehicle for their professional growth related to science?
2. How do teachers perceive that participating in collaborative professional learning transforms their students’ science learning?
3. What does teacher participation in the practice of collaborative professional learning related to science look like?

4. What initiatives has the school principal taken to engage teachers in collaborative professional learning for science?
5. What factors contribute to, or hinder, teacher collaborative professional learning related to science?

This chapter describes the research methodology and includes discussions around the following areas: (a) rationale for research approach, (b) description of the research sample, (c) methods of data collection, (e) analysis and synthesis of data, and (f) research credibility. This chapter culminates with a brief concluding summary.

Research Site/Participant Selection

Case boundaries. Merriam (1998) described the case of a case study “as a thing, a single entity, a unit around which there are boundaries” (p. 27), otherwise referred to as a bounded-system. The boundaries create a “distinction between the phenomenon being studied and its context” (Yin, 2014, p. 202), which permits the “rich, detailed, and concrete descriptions” (Patton, 2002, p. 438) of the perceptions of teachers and their school principals about the phenomenon within the inherently complex nature of the school environment.

The case was bounded by: (a) the geographical location being southwestern Ontario, Canada; (b) being a suburban elementary school; (c) the 2014-2015 school year for sufficient time to provide “close up” and “in-depth” analyses with “exemplary outcomes” (Yin, 2014, p. 62); and (d) elementary teachers teaching science needed to be previously engaged in CPL prior to commencing the study. In this capacity, I investigated teachers who were already aware of CPL to examine their perceptions of their current engagement in CPL, while avoiding investigating a new concept that teachers had to learn and integrate into their daily routine.

Purposeful sampling using a typical sample. Participants were selected using a nonprobabilistic, purposeful sampling strategy to have an optimal case site given the research questions (Patton, 1990). Merriam (1998) explained that “purposeful sampling is based on the assumption that the investigator wants to discover, understand, and gain insight and therefore must select a sample from which the most can be learned” (p. 61). Also, purposeful sampling yielded thick, robust descriptions about a teacher’s unique experience of CPL related to science. The selection of the case site was also related to

the idea that case study research is not meant to be generalizable in a positivist, statistical sense. The selection criteria for the participants were as follows: (a) each teacher participant must have been a full-time classroom teacher teaching science, and (b) the school principal must have already begun fostering an environment that allowed for teacher CPL so that professional trust, open communication, and the meaning of CPL was not a foreign concept to the teacher participants.

Participant Recruitment. Upon gaining ethics approval from the University of Western Ontario (see Appendix A) and from a school board in southwestern Ontario, local elementary school principals were contacted to begin recruiting participants. One school principal showed immense interest in participating in the study. I met with the principal in November 2014, explained the study in great detail, and provided him with the Letter of Information. The principal fit the criteria to participate, was eager to participate, and signed the consent. Following, the principal completed the Professional Development Continuum Rubric (see page 74 for details) and results showed that a culture of collaborative learning within the school had been initiated or was developing. Then, I provided the principal with Letters of Information and asked him to approach teachers who were teaching science to participate in the study. The principal was asked to briefly explain the project, provide teachers with a Letter of Information and indicate when I would be at the school to further discuss the study with the teachers. Teachers who were interested in participating in the research study met with me in November 2014 at the elementary school. I provided a detailed overview of the study and answered their questions. Those who were interested signed consent at that time. This meeting occurred for approximately one hour after school.

Case and Participant Description

A local school board was participating in CPL so I approached the board to determine if science was an area of interest for groups of teachers and their principal(s). Based on the case boundaries outlined above, three teachers from one school and their school principal participated in the research project. The small sample allowed for an in-depth analysis of the teacher engagement in CPL despite the constraints of the school-year schedule and teacher labour dispute nearing the end of the school year. The overview of the participants that follows is based on self-reported information

provided from a demographic questionnaire, and information provided during interviews and focus groups. The information provided context about the elementary school and the participants to situate the research study and conduct an in-depth case study.

Teacher participants. Table 1 provides demographic information for the teacher participants, who were provided pseudonyms by the researcher for the purpose of maintaining anonymity. The teachers were all women who taught various grade levels, were different ages, had various science backgrounds and experience teaching elementary school, as well as experience teaching elementary science classes. Each teacher taught science using the DRiVe Inquiry model as suggested by the local school board. The DRiVe Inquiry emphasized the inquiry process while incorporating literacy and numeracy skills. The “D” means the teacher demonstrates the investigation, the “R” means that students replicate the process, the “i” means that if needed, the teacher teaches a lesson(s) to help students better understand the concept, “V” means that students change a variable to test their prediction, and “e” means that the teacher and the students evaluate the results and consolidate student learning. Regardless of the grade taught, the DRiVe Inquiry model remains the same.

Anna. Anna was an experienced elementary teacher. She did not have an educational background in science but she was an experienced elementary science teacher because she taught science throughout her teaching career. Since September 2012, Anna participated in a series of CPL activities, some of which were based on science such as participating on the local boards Science Task Force. Other activities included participation in activities such as Numeracy Through Science Inquiry, Student-Centered Inquiry in Junior Science, Literacy Professional Learning (Part 1 and 2), Go Play Outside Project, Impact of Daily Part – Part-Whole Activities and the Understanding of Problem Solving, and being on the local Math Task Force.

Table 1

Demographic Data for Teacher Participants

	Anna	Elsa	Belle
Highest Degree of Education earned	Masters	Undergraduate	Undergraduate
Total number of science courses taken during their post-secondary education	0	20	3
Total years of teaching experience	13	5	25
Total years teaching elementary school science	13	2	5
Length of time teaching at their current school	1 st year	2 nd year	2 nd year
Teaching science to grade(s)	2/3	8	7
Total years of teaching the grades at time of study	2	2	23

Elsa. Elsa was the youngest teacher in the study in terms of age. However, she had the most formal education in science from her undergraduate studies: she took several courses in biology, chemistry, physics, nutrition science, biochemistry, agricultural, and botany. Since September 2012, Elsa continued her educational training by participating in professional learning activities such as: Special Education Specialty, The Fourth R, Librarianship (Part 1), and Kindergarten. Elsa also participated in other related science efforts such as the Sector Projects held by the local school board. The specific activities were about Putt Putt Boats and Trebuchets.

Belle. Belle had been teaching for the most number of years and was very comfortable trying to implement new teaching pedagogies. She had some formal education in science from her first year in undergraduate studies: biology, physics, and chemistry. Since 2012, Belle was involved in several professional learning activities: The Fourth R, Grade 7 and 8 physical education training, At Quest 2014, Summer Learning Conference, and Sector Projects (Putt Putt Boats and Trebuchets).

School Context. The school was one of the largest and most diverse elementary schools in the local school board. The school ranged from junior kindergarten to Grade 8 and had thirty-five teachers (29 female; 9 male) responsible for educating 591 students during the 2014-2015 school year. Of the 591 students, there were 100 English Language Learners, and 125 full day kindergarten students. The school operated on a 10-day cycle with a Balanced School Day to improve student learning with more uninterrupted instructional time and enhanced learning environments (see Figure 2). The schedule provided three blocks of instructional time ranging from 90 to 110 minutes, and two nutritional breaks either 40 or 50 minutes in length. In addition, the two Reflection Days were created by the school principal with the goal of encouraging teachers not to teach any new content, rather, check-in and solidify student learning.

Another aspect of the school was the way it was structured. The principal organized the primary division to have only combined classes to support the learning needs of the children in the classes. Each class had a combination of Grade 1 and 2, or Grades 2 and 3. Having five teachers teach Grade 2/3 or four teachers teach Grade 1/2 had an overarching purpose that lent itself to teacher collaboration. Furthermore, for each grade across the school, the principal scheduled timetables so that one block was designated to literacy, another for numeracy, and the other block was for subjects (such as gym and French) taught by someone other than a classroom teacher. While another teacher was teaching gym and French for example, the classroom teachers had their 480 minutes of preparation time in a 10-day cycle, 240 minutes over five work days, or 48 minutes per day, as mandated in the teachers' Collective Agreement.

Time	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
8:55-9:15 am					Reflection Day	Block One				Reflection Day
9:15-9:55 am										
9:55-10:35 am										
10:35-11:15 am	Activity Break/Nutrition Break									
11:15-11:55 am					Reflection Day	Block Two				Reflection Day
11:55-12:35 pm										
12:35- 1:05 pm										
1:05-1:55 pm	Activity Break/Nutrition Break									
1:55-2:25 pm					Reflection Day	Block Three				Reflection Day
2:25-2:55 pm										
2:55-3:25 pm										

Figure 2. Example of the Balanced School Day at Participant School.

In terms of teaching science, teachers were provided three options for when and where they wanted to teach science in their timetable: (a) they were able to incorporate science into other subjects such as literacy or numeracy, (b) they were able to designate a daily period to teach science, or (c) they were able to teach science in chunks. For example, they could teach a science unit for a number of weeks straight and incorporate other subjects like numeracy and literacy into the science topic. For instance, having students write a lab report for a language assignment and analyze graphs for mathematics. Whatever option teachers chose was dependent on their comfort and ability to teach science, and whether students had a rotary schedule. For example, Anna taught science in chunks. She felt this was best because she was able to conduct a science investigation over an entire week and be able to integrate literacy and numeracy into the science unit. This strategy worked well because she taught her students the core subjects because she was not on rotary. In addition, primary grade students do not have French class so there is

more flexibility in a primary teacher's schedule. On the other hand, Elsa and Belle designated one period every day to teaching science. They found this to be most effective considering they had a rotary schedule and thus, limited time with their students. Both the Grade 7 and 8 teachers taught two science classes per day to students in either Grade 7 or 8, but not both. So, Elsa taught two Grade 8 classes science, and Belle taught two Grade 7 science classes. The first class that both teachers taught was science during the second, 40-minute period of the first block (between 09:55 and 10:35), which was their numeracy block. Then the teachers taught the second class during the third period of the second block from 12:35 to 13:05. While one class of the grade sevens, for example, was taught science, the other class was being taught French. Elsa and Belle acknowledged that they only taught science during those periods. Science was not integrated into other subjects because of lack of time with the students, and the teachers were not teaching the core subjects to all students. Also, the requirements for report cards made it difficult to implement subject integration. The teachers had to ensure that they taught the same content to each class to avoid parental complaints.

School principal. From here on in, the school principal is referred to as Kristoff for the purpose of maintaining anonymity. Throughout the research study, Kristoff acted as a key informant and was “critical to the success of a case study” (Yin, 2014, p. 111). He provided “close up” and “in-depth” insights, as well as guided me into unfamiliar territory (Merriam, 1998) about a multitude of influences that influenced teacher CPL.

Kristoff was a male Caucasian who held a Bachelor of Kinesiology (Honors) and a Bachelor of Arts in Education. Kristoff held the position of principal for 13 years - three of which were at the case site. Additional positions Kristoff held during his career were: the vice principal at a secondary school for two years; a consultant for special education, behavior and autism for six years; and 10 to 15 years of experience looking after educational programs in clinical settings. Kristoff took five Additional Qualifying programs: principals, Specialist Physical Education, Specialist Special Education, Part 1, Counselling, and Special Education for Administrators. With regards to professional learning, Kristoff was an advocate and engaged in several CPL activities for professional growth. For example, since the

2012 school year, he participated in approximately three mental health workshops, four inclusion conferences, and several workshops about math and problem solving, collaborative inquiry, innovation in education, and Response to Intervention.

Kristoff was also an active member of the school as he regularly did walkthroughs for the purpose of strengthening the school culture, helping further develop teachers' instructional effectiveness and student achievement and to build stronger relationships with the students.

Data Collection

I employed multiple data sources including surveys, questionnaires, interviews, and focus groups. Within the focus groups, both oral and written information were provided. So, the triangulation of data involved the analysis of numerical and qualitative data, and questionnaires. Notably, although this research relied primarily on qualitative data sources from interviews and focus groups, I also employed self-efficacy, pedagogical discontentment, and belief surveys to make the findings as robust as possible (Stake, 2006; Yin, 2014). Merriam (1998) addressed that it is common in educational research to use multiple data collection techniques to “understand the case in its totality” (p. 134). The following table, Table 2, describes how I organized and facilitated data collection methods to address each research question, along with a brief rationale and description for using such method. Additionally, each survey is available in the appendices.

Surveys. To maintain confidentiality, I provided each teacher with an envelope with a seal and I labeled it with a determined number identifier that I provided. When each teacher completed the surveys, she sealed them in the envelope and gave it to Kristoff whereby he stored it in a locked cabinet within his secured office at the school until I retrieved the surveys on a set date.

Demographic Questionnaire. A demographic questionnaire asked teacher participants to identify their ethnicity, age, sex, highest degree of education, total number of undergraduate science courses completed, total years of teaching experience, total years of teaching at their current workplace, current grade they were teaching, the total number of years teaching their current grade, total number of years teaching elementary

school science, and to list any professional development activities they engaged in from September 2012 to September 2014. Kristoff had a similar demographic questionnaire but it also included asking about additional qualifying programs and general information regarding the school.

Table 2

Data Collection Methods and their Relationship to the Research Questions

Stage/Research Questions (RQ)	Instruments	Timeline	Rationale for method	Description
Stage: Recruited Kristoff and teacher participants	Professional Development Continuum Rubric	Nov. 2014	From Kristoff's perspective, to understand the degree teachers embraced the concept of CPL within the school at the beginning of the study	4-point scale
	Demographic information	Nov. 2014	To understand and frame the context of the participants and the school	Participant info. used for descriptive analyses
RQ: What are the perceptions of teachers and their school principal regarding collaborative professional learning related to science as a vehicle for their professional growth related to science?	Focus group with teachers	Feb. – Mar. 2015	To provide an in-depth understanding of the perceptions that teachers hold regarding their engagement in CPL related to science	Transcribed audio recordings of narrative data
	Interviews with school principal	Nov. 2014 – Apr. 2015	To understand Kristoff's opinion about CPL as a platform for teachers improving their science learning and teaching	
	Science Teaching Efficacy Belief Instrument	Dec. 2014	Provides numerical, primary information about whether teachers believe that they can succeed in teaching science	5-point Likert-type scales
	Science Teachers' Pedagogical Discontentment scale	Dec. 2014	Provides numerical, primary information to understand teachers affective response to the degree their practice meets their teaching goals	

(continued)

Stage/Research Questions (RQ)	Instruments	Timeline	Rationale for method	Description
RQ: How do teachers perceive that participating in collaborative professional learning transforms their students' science learning?	Focus group with teachers	Feb. – Mar. 2015	After identifying teacher engagement in CPL related to science, focus groups helped to understand whether their potential learning translated to improving their students' learning	Transcribed audio recordings of narrative data
RQ: What does teacher participation in the practice of science collaborative professional learning look like?	Professional Development Log	Pilot: Nov. 2014 Dec. – Apr. 2015	Teachers monthly logs provided a means to explore: what teachers did, when they did it, who they collaborated with, where it happened, for how long, and the perceived learning outcomes	Record of teachers' engagement in CPL per month
	Focus group with teachers	Feb. – Mar. 2015	Data retrieved from the combination of logs and interviews provided an understanding of teacher engagement in CPL regarding science	Transcribed audio recordings of narrative data
RQ: What initiatives has the school principal taken to engage teachers in collaborative professional learning for science?	Interviews with school principal	Nov. 2014 – Apr. 2015	To gain an in-depth understanding of the most salient components of Kristoff's role in facilitating teacher CPL related to science.	Transcribed audio recordings of narrative data
	Focus group with teachers	Feb. – Mar. 2015	To understand whether teachers agree with Kristoff's perceptions about his role in facilitating teacher CPL related to science	

(continued)

Stage/Research Questions (RQ)	Instruments	Timeline	Rationale for method	Description
RQ: What factors contribute to, or hinder, teacher collaborative professional learning related to science?	Beliefs about Reform Science Teaching and Learning	Feb. 2015	To understand teacher beliefs about science teaching along a continuum from traditional to reform-minded	4-point Likert-type scale
	Interviews with school principal	Nov. 2014 – Apr. 2015	To understand salient influences, internal and external to the school environment, that influence teachers' ability to engage in CPL related to science	Transcribed audio recordings of narrative data
	Focus group with teachers	Feb. – Mar. 2015		

Professional Development Continuum Rubric. The purpose of Kristoff and each teacher participant completing the rubric was to provide the researcher with an indication as to whether the case was an appropriate fit for the research study as the researcher required that the participants were already familiar with the concept of collaborative professional learning. Kristoff and each teacher participant individually assessed each element of the rubric (mission, shared vision, shared values, goals, collaborative culture for teachers, collaborative culture for administrator/teacher relations, action research, continuous improvement, and focus on research) according to what stage of development they believed was happening in the school. The rubric was a modified version of Dufour et al.'s (2006) rubric (see Appendix B). The continuum has four stages: *Pre-initiation* (1 point), *Initiation* (2 points), *Developing* (3 points), and *Sustaining* (4 points). Responses could range between 10 and 40 for the instrument, but as expressed in the “case boundaries” section above, I chose a school that was at least in the initiation stage with regards to teacher engagement in CPL. Thus, the acceptable range for Kristoff, who represented the school, had to be between 20 and 40. On the other hand, the teachers’ scores were not taken into consideration when selecting the case. They completed the rubric during the first focus group and their results were compared to Kristoff’s in the analysis.

Science Teaching Efficacy Beliefs Inventory –A (STEBI-A). The STEBI-A survey designed by Riggs and Enochs (1990) is unique in the sense that it measures in-service teacher beliefs about their ability to teach science, and their ability to influence student learning related to science (see Appendix C). The STEBI-A has two subscales related to Bandura’s (1977, 1986) social cognitive learning theory and Gibson and Dembo’s (1984) “Teacher Efficacy Scale”. The two subscales are: (a) Personal Science Teaching Efficacy (PSTE) measuring self-efficacy, and (b) Science Teaching Outcome Expectancy (STOE) measuring outcome expectancy. PSTE is defined as an individual’s “belief that he or she [personally] has the skills and abilities to bring about student learning” (Dembo & Gibson, 1985, p. 175). The STOE reflects whether teachers have the confidence in their effective teaching to overcome factors that may compromise student learning. While the instrument is designed to measure both PSTE and STOE, I only utilized the items measuring PSTE because: (a) authors (e.g., Enochs & Riggs, 1990;

Huinker & Madison, 1997; Plourde, 2002) have cited a lower reliability coefficient for outcome expectancy beliefs, (b) Bandura (1997) suggested that perceived self-efficacy is a better predictor of behavior than outcome expectancy beliefs, and (c) the two constructs were treated separately and only reflected either self-efficacy or outcome expectancy, not a combination of both (Riggs & Enochs, 1990). These concerns have led to the suggestion that outcome expectancy is a less definitive construct than self-efficacy, and thus, more difficult to accurately measure (Riggs & Enochs, 1990; Tschannen-Moran et al., 1998). For these three reasons, researchers (e.g., Bursal, 2010; McDonnough & Matkins, 2010) have argued that it may be more valuable for researchers addressing science teaching efficacy beliefs to focus their attention on the Personal Science Teaching Efficacy scale.

Personal Science Teaching Efficacy items are “I”-statements that reflect the level of confidence that teachers have in their effectiveness as teachers who teach science. The survey was completed once at the beginning of the study. The study is composed of 13 Likert scale items, each of which have five response ratings: *strongly agree* (5 points), *agree* (4 points), *uncertain* (3 points), *disagree* (2 points), and *strongly disagree* (1 point). According to Riggs and Enochs (1990), the self-efficacy reliability scale is .92. Scores on the negatively worded items (2, 4, 5, 7, 9, 10, 11 and 13) were first reversed prior to analysis so that “strongly agree” received a score of one. Following Haney and colleagues (Haney et al., 2002) and Lumpe and colleagues (Lumpe, Haney, & Czerniak, 2000), the total PSTE scores were divided into equal thirds to separate teacher participants into groups of low, medium, or high levels of PSTE. The range of low, medium, and high scores is from 13 to 65, where scores between 13 and 30.33 were considered low, scores between 30.34 and 47.66 were considered medium, and scores between 47.67 and 64.99 were considered high. A higher score was indicative of a teacher having higher self-efficacy regarding their science teaching.

Science Teachers’ Pedagogical Discontentment scale (STPD). The *STPD* (see Appendix D) created by Southerland and colleagues (Southerland et al., 2012) is a theoretical tool used to understand in-service “science teacher pedagogical dissatisfaction” (p. 485): one facet of teachers’ affective state that arises when they experience a discrepancy between their science teaching beliefs, their goals, their actual

classroom practices, and student outcomes. Or, the unease with teaching practices experienced by teachers who are ready to change their practice (Southerland et al., 2012).

According to the STPD, there are six categories of this affective state: (1) ability to teach all students science, (2) science content knowledge, (3) balancing depth versus breadth of instruction, (4) implementing inquiry instruction, (5) assessing science learning, and (6) teaching nature of science (Southerland et al., 2012). The results from the STPD help provided the researcher with a deeper understanding of teachers' idiosyncratic response to reform participation in CPL. The scale is composed of 21 Likert style items, each of which has five response ratings: *very high discontentment* (5 points), *significant discontentment* (4 points), *moderate discontentment* (3 points), *slight discontentment* (2 points), and *no discontentment* (1 point). The 21 items divide into six subscales of pedagogical discontentment that are distinct constructs with high reliability values (measured by Cronbach's alpha internal consistency reliability analysis) that are provided in Table 3. For the total instrument, the Cronbach's alpha value is .93. For the instrument as a whole, scores range between 21 and 105. Teacher's scores were first totaled per subscale and for the entire instrument. A hard fast range to differentiate pedagogically content from discontentment fails to exist (S.A. Southerland, personal communication, February 15, 2015). I understood teacher discontentment based on whether their total scores were below the mid-point of 63. Total scores above 63 are reflective of teachers being more pedagogically discontentment with their science teaching, whereas scores below 63 are reflective of teachers embodying the belief that they are content with their science pedagogy.

As Southerland and colleagues (2012) acknowledge, pedagogical discontentment is one facet of several affective states. Given this, to illuminate teacher receptivity to changing their teaching practice by participating in CPL related to science, I compared the results of the STPD survey to the PSTE scores and followed the Model of Teacher Self-efficacy, Contentment and Anticipated Changes in Practice (see Chapter II, Pedagogical Discontentment section) by Southerland et al. (2011a).

Table 3

STPD Scale Subscales and their Reliability, Items, and Range

Subscales	Reliability	Items	Score Range
Ability to teach all students science (AL)	.82	1, 4, 9, and 10	4 to 20
Implementing inquiry instruction (IB)	.87	5, 6, 7, and 19	4 to 20
Science content knowledge (SC)	.77	12, 13, 14, and 16	4 to 20
Balancing depth versus breadth of instruction (DB)	.89	2, 20, and 21	3 to 15
Assessing science learning (AP)	.80	3, 11, and 17	3 to 15
Teaching nature of science (TN)	.85	8, 15, and 18	3 to 15

Beliefs About Reformed Science Teaching and Learning (BARSTL). The BARSTL was developed by Sampson, Grooms and Enderle (2013; see Appendix E) and is designed to map elementary teacher beliefs about science teaching and student learning along a continuum from traditional to reform-minded. The conceptual development of the questionnaire was developed based on the national science education reform movement (Howard, 2014; Khan, 2012). So, the questionnaire is based on the recommendations and standards for teaching science education (National Research Council, 1996). Sampson et al. (2013) considered reform views as those consistent with constructivist philosophies. The authors believed that teacher beliefs about the nature of science and the learning and teaching of science act as an influential filter as to whether and how teachers enacted reform-based instructional strategies in their classroom practice. The value of using the BARSTL was to provide insight into teacher views about teaching science, and to identify potential barriers to their implementation of constructivist-based science teaching. The value of using the BARSTL for this research was that it helped to inform the researcher about the extent to which teacher beliefs lean toward either traditional or constructivist means to teaching and learning science. Based on that understanding, the BARSTL results may help inform the design of future collaborative professional learning

programs or activities in the sense that if teachers hold traditional beliefs, the learning programs need to work on transforming teacher beliefs from traditional to reform based so that teachers understand the importance and value to teaching inquiry based science.

The questionnaire included 32 items that are distributed into four sub-dimensions, each which include eight questions, four representing traditional perspectives and four representing reform, or constructivist perspectives. The subscales were: (a) How people learn about science (traditional: 3, 4, 6, 7; reformed: 1, 2, 5, 8), (b) Lesson design and implementation (traditional: 11, 12, 15, 16; reformed: 9, 10, 13, 14), (c) Characteristics of teachers and their leaning environment (traditional: 18, 21, 22, 23; reformed: 7, 19, 20, 24), and (d) The nature of the science curriculum (traditional: 26, 27, 29, 31; reformed: 25, 28, 30, 32). Two internal consistency estimates of reliability were computed by Sampson et al. (2013): Split-half coefficient as a Spearman-Brown corrected correlation (.80) and coefficient alpha (.77), indicating that the questionnaire is a reliable instrument for measuring elementary teachers reformed beliefs about teaching and learning science. The descriptions for each subscale are provided in Table 4.

The items were scored using a 4-point Likert scale: *strongly agree* (4 points), *agree* (3 points), *disagree* (2 points), and *strongly disagree* (1 point). In scoring the responses, “strong agreement” with a reform-based item is assigned a score of 4 and “strong disagreement” is assigned a score of 1. Items representing the traditional perspectives were reversed scored, in that 4 points were given to items marked as “strongly disagree” and 1 point was assigned to items marked as “strongly agree”. Teacher’s scores were first totaled per subscale and for the entire instrument. Total possible scores range from 32 to 128 points, and the potential range per subscale was 8-32. The results were addressed according to the total scores like other researchers in their dissertations (e.g., Howard, 2014; Khan, 2012). The reason is that the total scores are used to indicate whether teachers hold traditional or constructivist perspectives about teaching and learning science.

To verify that making such inference is acceptable, Sampson et al. (2013) first assessed content validity by having a panel of experts review the items in each subscale. They concluded that the items were consistent with reformed and traditional perspectives and were evenly distributed through the questionnaire.

Table 4

Dimensions of Traditional and Reformed Minded Beliefs Associated with each Subscale of the BARSTL

BARSTL Scales	Traditional Perspective	Reformed Perspective
How people learn about science	Compared with “blank slates” Learning is an accumulation of information	What students learn is influenced by their existing ideas. Learning is the modification of existing ideas.
Lesson design and implementation	Teacher-prescribed activities Frontal teaching-telling and showing students Relies heavily on textbooks and workbooks	Student-directed learning. Relies heavily on student-developed investigations, manipulative materials, and primary sources of data.
Characteristics of teachers and the learning environment	The teacher acts as a dispenser of knowledge Focus on independent work and learning by rote	The teacher acts as a facilitator, listener, and coach. Focus on learning together and valuing others ideas and ways of thinking.
The nature of the science curriculum	Focus on basic skills (foundations) Curriculum is fixed Focus on breadth over depth	Focus on conceptual understanding and the application of concepts. Curriculum is flexible, changes with student questions and interest. Focus on depth over breadth.

To evaluate construct validity, Sampson and colleagues conducted a correlation analysis on each of the four subscales and found that they could predict the final overall score (Allen, 2013). Thus, based on the range of total scores, a score of 80 represents the median score; a balance approach and belief that elements of both lecture and constructivist teachings are effective. Higher inventory scores are reflective of reformed pedagogical content beliefs about the teaching and learning of science, or a constructivist student-centered attitude. Lower scores are reflective of embodying beliefs that are more

traditional in the teaching and learning of science, otherwise known as a teacher focused, lecture-oriented attitude toward learning.

Professional Development Log. Teachers recorded their participation in CPL activities regarding science education on a monthly basis to understand the extent to which teachers participated in CPL, what was happening during the activity, and whether they felt their learning transformed their teaching. Unveiling the big picture of what teachers did to further their learning and teaching regarding science had the potential to understand CPL in real time as teachers could record their activities as they occurred – also potentially eliminating recall bias (Yoon, Garet, Birman, & Jacobson, 2007). The concept of the professional development log originated from the Professional Development Activity Log created by the American Institutes for Research (see Yoon et al., 2007). The Professional Development Activity Log was developed to capture the complexity of teacher professional development activities and to “examine the scope, nature, and quality of a wide array of professional development activities that teachers take part in over an extended period of time” (p. 7) for the purpose of improving their instruction related to mathematics and science education.

I created the professional development log to include key characteristics of CPL as discussed in Chapter II (see Appendix F). The professional development log was also created to be user friendly on Microsoft Excel. Other than potentially writing responses to provide additional information in columns titled “other” and in the last three columns asking teachers to “describe any changes to your instructional repertoire”, “describe why you may feel your teaching knowledge changes from this activity” and “key ideas/thoughts/other notes”, the remainder of the columns were completed by drop-down menu embedded in the document. I first piloted the professional development log for one month with the teachers to receive their feedback and to ensure that they were comfortable using it. Feedback included one teacher expressing that it was easier to write her activities on paper when it happened and then fill out the professional development log at the end of the month. However, this teacher did not complete the log on paper, rather, she imputed her entries directly into the computer. Otherwise she forgot about activities that happened by the time she completed the log. To help prompt the teacher participants to send me their professional development log at the end of each month, I

emailed each teacher individually as a kind reminder to email me their log at their convenience, and that I was open to any feedback concerning the logs and the research study in general.

Interviews and focus groups. Interviews being the “best technique to use when conducting intensive case studies of a few selected individuals” (Merriam, 1998, p. 72) were conducted because they were a means of obtaining “the descriptions and interpretations of others” (Stake, 1995, p. 6), and for the researcher to get “in and on someone else’s mind” (Patton, 1990, p. 278). In this capacity, interviewing and facilitating focus groups with Kristoff and the teacher participants served to address the research purpose and to gain an understanding of the participants’ reflections on the issue. Notably, Kristoff was engaged in individual interviews, whereas the teachers collectively participated in focus groups. Kristoff and the teachers were interviewed separately to avoid power relations and to create a non-threatening environment so the teachers felt “comfortable to discuss their opinions and experiences without fear that they [would] be judged” (Hennink, 2007, p. 6) by Kristoff. Also to help mitigate a power relation between researcher and teacher participants, I created a rapport with each teacher prior to the focus groups by communicating with them face-to-face and via email. With regards to Kristoff, we had very brief phone conversations for the sole purpose of setting a date and time for each meeting.

Each interview and focus group was developed as a semi-structured format to have a measure of control over what I wanted to discuss with the participants, yet be able to inquire and probe about topics that arose during the interviews and focus groups to be able to further discuss emergent ideas. Before conducting each interview and focus group, I provided the appropriate participant(s) with the interview guide (a list of questions I intended to ask) at least three working days prior to the interview. The guidelines contained specific questions I wanted to ask and more open-ended questions with probes in case I wanted to dive deeper into the topic. The interview guide was also helpful to the participants because it removed the possible anxiety they may have had about the process by giving them time to think about the questions and their answers. Also, the guide enabled the participant(s) and I to have focused discussions about the

topics being discussed by providing a means for redirecting the interview if it started to stray in different direction(s).

Focus groups with the teachers. Focus groups were conducted with the teacher participants as they are “ideal” for generating collaborative discussions and for exploring the experiences teachers have, and their point of view, beliefs, needs, and concerns (Kitzinger, 2005). Given that this study was about collaboration, focus groups were a better means of data collection than individual interviews. The focus groups were not meant to have the teachers reach a consensus on the discussed issues. Rather, they were meant to “encourage a range of responses which provide a greater understanding of the attitudes, behavior, opinions or perceptions” (Hennink, 2007, p. 6) of the teachers “to get closer to the data” (Ivanoff & Hultberg, 2006, p. 126). At times, I determined follow-up questions that were necessary and then encouraged teachers to elaborate or clarify comments. Seidman (1998) defended this practice explaining that the interviewer begins “each interview with a basic question that establishes the purpose and focus of the interview, it is in response to what the participant says that the interviewer follows up, asks for clarification, seeks concrete details, and requests stories” (p. 66). True to Seidman’s point, I asked follow-up questions when appropriate and clarified questions that were specific to each focus group. Throughout the focus group, teachers referred to their experiences and opinions so both commonalities and differences existed.

The primary aim of the focus groups was to facilitate “collective conversations” (Kamberelis & Dimitriadis, 2008, p. 375) that included an array of collective activities (Kitzinger, 2005) to further develop the responses teachers had as they evolved through conversation (Barbour, 2007). The collective activities included: (a) directly asking questions to generate responses from the teacher participants, (b) six activities that required jotting down ideas on large Bristol paper, occasionally using sticky notes or directly writing on the paper so that teachers could independently and collaboratively discuss specific topics, and (c) teachers individually writing their responses to specific questions that were determined beforehand by the researcher. Table 5 provides a description of the interviews and focus groups with the participants. Notably, Kristoff and the teachers were involved in their interviews and focus groups for nearly equal amounts of time. Also, all meetings took place at the school, with the exception of one that is

noted by the asterisk (*); it took place at the university of the researcher for reasons of convenience for both the researcher and Kristoff.

Informal conversational interviews. In addition to formal interviews, Kristoff and I engaged in what Patton (1990) called “informal conversational interviews”. During the course of collecting data, this type of interview occurred spontaneously at the local university. They were also very short in time – less than 10 minutes on average. To provide a couple of examples of these discussions, I was scheduled to meet with the teacher participants at their school, but one teacher was ill and absent. As such, Kristoff informed me that the meeting was cancelled and needed to be rescheduled. A second example of was Kristoff expressing one of the situations he had to deal with that began one morning at 7:30 AM- the bottom floor of the school flooded and arrangements had to be made as to where to place students and their teachers by the time classes began at 8:55 AM. Due to the informal and occasionally confidential nature of the discussions, they were not recorded and transcribed because they were not systematic or comprehensive (Patton, 1990). However, the interviews were valued because they helped to build a rapport with Kristoff and provided insights about situations that occurred within the school. Given this, the interviews spoke volumes to the multi-faceted nature of being a school principal, and they helped me to understand why teachers’ continual science learning and teaching is only one of the responsibilities Kristoff oversees.

Table 5

Description of the Interviews and Focus Groups with the Participants

Participant(s)	Date	Time (min.)	Brief Description
Kristoff	Nov. 2014	60	This interview primarily captured the culture of the school including Kristoff's leadership style, teacher timetables, and the concept of CPL in the educational system.
Kristoff	Dec. 2014	80	The main topics discussed were: Kristoff's leadership initiatives for teacher CPL, the lack of time and money for teacher CPL, the teachers' eagerness to participate in CPL related to science, and the need modify the current educational system to place equal value on subjects.
*Kristoff	Dec. 2014	30	Topics included: ministry initiatives that supported and influenced Kristoff's ability to manage and promote science teacher CPL, how CPL related to science could become a regular occurrence within the school day, and how CPL activities helped to improve teachers' science teaching.
Kristoff	Mar. 2015	80	After completing the two focus groups with the teachers, I gathered further information primarily about ministry related influences on teachers CPL from Kristoff to compare his perspective to that of the teachers.
Kristoff	Apr. 2015	60	This interview was the most open-ended. I presented Kristoff with the tentative findings and asked for clarification.
Total Meeting Time: 5 hours and 20 minutes			
Anna & Elsa	Feb. 2015	20	This was a brief meeting to set up a time for both focus groups. Teachers had the opportunity to discuss feedback from participating in the study so far.

(continued)

Participant(s)	Date	Time (min.)	Brief Description
Anna, Elsa, & Belle	Feb. 2015	150	Focus Group 1. The teachers discussed the reality of their CPL related to science within their public school and out of the school. They spoke about school and ministry related factors that influenced their CPL, and what they would like to have happen to make CPL for science more predominate in their everyday routine. Teachers engaged in oral discussions, collaborative writing exercises, and individual writing exercises that involved answering specific questions, including the Professional Development Continuum rubric.
Anna, Elsa, & Belle	Mar. 2015	150	Focus Group 2. First, I clarified questions from the first focus group. Then the focus was on teachers describing their engagement in CPL related to science within and out of the school, and whether and how this tailored their science teaching. The teachers engaged in oral discussions and collaborative writing exercises.

Total Meeting Time: 5 hours and 33 minutes

Data Analysis

Surveys. The survey data was analyzed in the form of descriptive data using Microsoft Excel. The value of the survey data was to gather information about the teacher beliefs (self-efficacy, pedagogical discontentment, epistemological beliefs) that may have influenced their participation in CPL. It was not sufficient to rely solely on the quantitative survey instruments, so qualitative data from the focus groups were used to triangulate the data (Pajares, 1992). Going back and forth between the qualitative data and the survey results allowed me to generate an understanding of influential factors that affected the teacher participants' engagement in CPL.

Considering that the Science Teaching Efficacy Beliefs Inventory-A questionnaire, the Science Teachers' Pedagogical Discontentment scale, and the Beliefs About Reformed Science Teaching and Learning questionnaire are each measured by ordinal scales to rate the degree to which participants are discontent, or agree with the way in which science should be learned and taught, or the extent to which the participants agree with the statement about their capability of executing a task, the distance between

the scales is not measurable. Whether ordinal data can be converted to numbers and treated as interval data has been a longstanding controversy particularly because of the unclear meaning of descriptive statistics derived from means and standard deviations (Sullivan & Artino, 2013). For instance, for the Science Teachers' Pedagogical Discontentment scale, what does the average of "moderate discontentment" and "significant discontentment" mean? Or, in terms of the Beliefs About Reformed Science Teaching and Learning questionnaire, what does the mean numerical value between "agree" and "strongly agree" mean? Considering that the means are not helpful to understanding the participant responses, "experts have contended that frequencies (...) should be used for analysis instead" (pp. 541-542). Also, because of the small participant pool, using means and standard deviations may not yield a sufficiently accurate response while interpreting the data.

Professional Development log. The results of the monthly professional development logs from each teacher were condensed into a descriptive table to highlight the CPL activities that each teacher engaged in over the course of five consecutive months. Teachers' written statements where they logged their thoughts/notes/ideas, or reasons for why they may have changed their teaching knowledge or instructional repertoire were used to support or refute findings from the survey analysis.

Interviews and Focus Groups. The protocol for qualitative data analyses – interviews and focus groups – is outlined in Table 6. It explains the procedure by which each interview and focus group was transformed from raw data to final themes.

Table 6

Summary of the Data Analysis Protocol for Interviews and Focus Groups

Stage	Process
Ongoing analysis during data collection included transcribing each interview/focus group after it happened, and organizing the data	<ul style="list-style-type: none"> • To “make sense of the data” for meaning-making (Merriam, 1998, p. 178), data analysis began immediately following document collection to refine and reformulate future interview questions based on emerging topics. • Each interview and focus group was recorded using a Sony digital voice recorder (ICDUX543B) to ensure the proper record of the discourse. After each interview and focus group, I copied the digital recording from the recorder to my secured computer and saved the file under pseudonyms to protect confidentiality. The digital voice recorder was linked to a voice recognition software, Nuance’s Dragon Naturally Speaking, Premium (version 13), that automatically transcribed the voice recordings. After the interview was transcribed by Dragon Naturally Speaking, I went through the interview and focus group to ensure the transcription was accurate, and to specify who said what. I also numbered each line of the transcript to be able to easily retrieve quotations. • Each transcription was complete within one week of the interview and focus groups.
Familiarizing myself with the data	<ul style="list-style-type: none"> • Transcripts were read several times and preliminary notes were taken in a journal specific for data collection and analysis. This helped me to immerse myself in the data once it was all collected, to view it from a holistic perspective, and to begin to identify the big ideas.
Data reduction, category development, and identification of participant quotations	<ul style="list-style-type: none"> • Using a template by Bloomberg and Volpe (2012), I summarized the data from each interview and focus group into smaller units of information (see Appendix G for an example). I first began by conducting descriptive coding by developing categories that applied to each unit. Descriptive coding method was selected because it related to my research purpose about understanding the phenomenon of interest and addressing research questions such as “what factors influence...?” (Saldana, 2013, p. 61).

(continued)

Stage	Process
	<ul style="list-style-type: none"> • For each section of the transcript that was descriptive coded, I: (a) identified the page number of the unit from the transcript to easily refer to the transcript; (b) identified quotes and referenced them according to their line number; (c) identified a potential research question to which the unit may apply to for the purpose of beginning to shape the data into a presentable form; and (d) described the significance of the document, wrote about salient questions to consider that emerged from the transcript, and I wrote about any internal dialogue that may have sparked further thinking about the data – what Strauss (1987) referred to as memoing. • Considering that coding is a “cyclical act” (Saldana, 2009, p. 8) and “leads you from the data to the idea, and from the idea to all the data pertaining to that idea” (Richards & Morse, 2007, p. 137), I engaged in a “codifying” process (Grbich, 2007, p. 21) whereby with each interview and focus group data, I coded the new data and went back to previous interviews and focus groups to re-code for the purpose of “consolidat[ing] meaning and explanation” (Grbich, 2007, p. 21), and to refine the categories. This is similar to what Patton (1990, 2001) calls an inductive analysis. • Once all units of information were placed under categories, I reviewed them for overlap because some had similar characteristics that were collapsed. • Note that not all units of information were relevant to the research questions but they were not discarded in case they became categories on their own.
Code Mapping & Pattern coding leading to the interpretation of the data	<ul style="list-style-type: none"> • Each unit of information, along with its identification, theme(s), and quotations were cut into individual pieces and manually organized on my floor according to which research question I believed it was tailored to at that time. Once each unit of information was placed with its research question, I identified trends, patterns, and relationships within and across each research question to assign themes (Saldana, 2013). Upon looking at all units of information from a broad perspective, I began moving units of information to have each unit gathered into themes. I also organized each unit of information within a theme into a coherent narrative on the floor, which still required shifting units between themes. This process continued until I was confident with the narrative for each theme.

(continued)

Stage	Process
Corroborating and legitimating coded themes	<ul style="list-style-type: none"> After writing the first draft based on the narratives laid out on the floor, I further clustered the themes by analyzing the interaction of the text, the categories and the themes. This involved several iterations to further cluster the core themes that underpinned the phenomenon as described in the raw data (Fereday & Muir-Cochran, 2006).

Provisions for Trustworthiness

Because of the qualitative nature of this research study, a “key concern is understanding the phenomenon of interest from the participants’ perspective, not the researchers” (Merriam, 1998, p. 6) because as the researcher, I was responsible for collecting data, analytical subjectiveness and developing relationships (Merriam, 1998). Being mindful of issues of validity and dependability of the qualitative research design, I followed various protocols by experts in the related field to “present insights and conclusions that ring true to readers, educators, and other researchers” while obeying all ethical protocols during the research (Merriam, 1998, p. 198-199).

Internal Validity. Merriam (1998) describes internal validity as the “question of how research findings match reality” (p. 201). I undertook three means to ensuring internal validity: triangulation, member checks, and researcher’s bias.

Triangulation. The methodological design was strengthened by using “multiple sources of data, and multiple methods to confirm the emerging findings” (Merriam, 1998, p. 204) as “an attempt to secure an in-depth understanding of the phenomenon in question” (Denzin & Lincoln, 2005). As shown in Table 2, a total of four methods were conducted: questionnaires, surveys, interviews, and focus groups. In addition, during the focus groups, teachers were asked to verbally share their opinions and beliefs, as well as complete charts that I created on selected topics. The triangulation of this data helped to increase my confidence about the interpretations of the data (Stake, 1995).

Member Checks. Member checking was another strategy applied to this case study. Merriam (1998) describes member checking as “taking data and tentative interpretations back to the people from whom they were derived and asking them if the results are plausible” (p. 204). Although member checks are not without fault, they

decrease the incidence of incorrect interpretation of data (Creswell, 2007). During both interviews and focus groups, I restated and/or summarized information provided by the participant(s) to determine accuracy. Secondly, I provided a preliminary report of the research findings to Kristoff for his review for authenticity. I did not provide a preliminary report of the research findings to the teacher participants because the teachers were on work-to-rule during the end of the data collection period. I felt that it was best not to ask the teachers to engage further in the research study as Anna, Elsa, and Belle had already contributed a significant amount of time and dedication toward the research study.

Reliability. In line with qualitative research, the term reliability refers to “whether the results are consistent with the data collected” (Merriam, 1998, p. 206). To strengthen the reliability of this case study, as suggested by Merriam (1998), I took three measures: (a) I designated Chapter III to the theoretical framework – Situated Learning Theory by Lave and Wenger (1991) to guide my perception of collaborative professional learning; (b) I used data triangulation as discussed above, and (c) I maintained an audit trail detailing how data were collected and how themes were derived so that the readers of the case study can support the findings. Throughout the research, I kept a journal that included all field notes, reflections, and any event that happened while collecting data. I also provided sufficiently in-depth descriptions of “how data were collected, how categories were derived, and how decisions were made throughout the inquiry” (Merriam, 1998, p. 207). The three measures helped to ensure that the research findings were shaped by the participants’ data rather than my personal bias, motivation, or interest (Guba & Lincoln, 2005).

External Validity. As with case study research, “a single case or small non-random sample is selected precisely because the researcher wishes to understand the particular in depth, not to find out what is generally true of the many” (Merriam, 1998, p. 208). Based on the sampling procedure I used to conduct this case study - non-random, purposeful sampling – the themes of the research can be extrapolated to “other situations under similar, but not identical conditions” (Patton, 1990, p. 489). Given this, I provided thick, rich descriptions of the context and participants to claim relevance to broader contexts (Schram, 2003).

Chapter Summary

This chapter described a detailed description of the methodology and qualitative case study used to examine multiple and completing views of elementary teachers' engagement in CPL. The three participating elementary school teachers – Anna, Elsa, and Belle - who taught science and their school principal – Kristoff – were purposefully selected. Data collection methods employed included three surveys, two questionnaires, five months of professional development logs (excluding the pilot month), five interviews, and two focus groups. Data collection and analysis occurred simultaneously so that all themes were addressed and compared with the research literature through the lens of Situated Learning Theory. To establish trustworthiness of the case study, a series of events took place that Merriam (1998) suggested: data triangulation, member checking, outlining my bias, recording an audit trail, and addressing the generalizability of the research. Although the conclusions were not meant to be generalizable, the intent was to provide sufficient information to apply the conclusion to elementary schools with a similar, but not identical school environment. The next chapter will discuss the results of the analyses described above.

CHAPTER V: RESULTS

The single case study design allowed for an intensive and authentic investigation into the multiplicity of factors affecting teacher participation in collaborative professional learning (CPL) related to science education. Unveiling multiple and competing perspectives that teachers (Anna, Elsa, and Belle) and their school principal (Kristoff) held helped to recognize and appreciate the tensions characterizing teacher engagement in CPL related to science, and to potentially help align teacher efforts and system goals. The purpose of this chapter is to provide the reader with a better understanding of the perspective of the participants about CPL related to science. This chapter presents the key findings obtained from the five interviews completed by Kristoff, one professional development rubric completed by Anna, Elsa, Belle, and Kristoff, and four surveys, five consecutive months of professional development logs, and two focus group interviews with Anna, Elsa, and Belle. The research findings are presented in a narrative manner with extensive samples of quotations from each participant to provide a rich description of the findings.

The findings are presented in two sections. Section 1 includes two primary themes that emerged from the interviews and focus groups:

1. Kristoff's supportive leadership toward teacher engagement in CPL for the purpose of developing and sustaining teacher's ownership of their engagement in CPL included establishing a school culture with an internal structural system to encourage teacher engagement in CPL, and organizing and supporting CPL opportunities related to science outside of the school environment.
2. Teacher's ability to engage in, and learn from in-situ CPL related to science was limited by factors stemming from the Ontario education system and local school board. Mitigating the issues includes placing equal emphasis on all subjects in Ontario's elementary education and redistributing time and fiscal resources to regularly include science coaches in the school environment.

Section 2 includes one theme that arose from the descriptive statistics from the surveys and the professional development logs, which was then supported by qualitative data collected during the focus groups and interviews. Below is the major theme that emerged:

3. Teachers' beliefs (self-efficacy, pedagogical discontentment, epistemological beliefs) appeared to be positive influences on their openness to CPL related to science. Each teacher was receptive to engaging in CPL related to science on an ongoing basis to improve their science teaching, and in turn, student's science learning.

Section 1

Theme 1: Kristoff's supportive leadership toward teacher engagement in CPL for the purpose of developing and sustaining teacher's ownership of engagement in CPL included establishing a school culture with an internal structural system to encourage teacher engagement in CPL, and organizing and supporting CPL opportunities related to science outside of the school environment.

Kristoff held the position of school principal at the elementary school for three years before the beginning of this study. During this time, he focused on building school-wide cultural and structural supports to facilitate, encourage, and sustain teacher engagement in CPL across all subjects. The development of the culture was acknowledged by Kristoff and the teacher participants. Based on the overall scores of *The Professional Development Continuum Rubric*, Kristoff and Belle perceived that in general, the teachers in the school were in the developing stage of CPL; most teachers endorsed the concept of CPL and were modifying their thinking and teaching based on their learning from the CPL activities. In contrast, Anna and Elsa perceived that the teachers in the school were in the initiation stage of CPL; the concept of CPL was being addressed within the school, but engagement in CPL had not affected the pedagogy of many teachers. Although the study participants held differing opinions about teacher's level of engagement with the school, there was a consensus that Kristoff did develop a culture of CPL within the school environment. The reasons are discussed below.

Supportive leadership

Kristoff's leadership for establishing and sustaining teacher engagement in CPL was focused on two aspects:

1. Kristoff modeled himself as an educator who continuously participated in CPL so that he led by example when encouraging and supporting teacher engagement in CPL.
2. Kristoff adopted a bottom-up leadership style that enabled teachers to develop a sense of ownership over their CPL.

Kristoff continuously participated in CPL and encouraged and supported teacher engagement in CPL. Kristoff believed that one of the most important and influential means of encouraging and supporting his teaching staff to engage in CPL for themselves was to personally and continually engage in, and promote CPL. Kristoff said that he was always “modeling myself as a professional educator” so that teachers saw and understood that. In fact, “PD for me is daily” as Kristoff explained with great enthusiasm. Kristoff provided a glimpse of his engagement in CPL to support his claim about being continually involved in professional learning and acting as a positive role model to his teaching staff:

I'm interested in a concept called collective impact. It's about collaboration. So I go to a conference in [city] with people from all over the world to collaborate about what we can do better. At the same time, [professor] calls me and asks if I want to be involved in a project on [topic] so I'm in! Then she says, we are going to include the work about implementation science. I've never heard of implementation science before! I dig through the research literature and well, implementation science is everything. Prior to that, the board offered administrators an introductory session on cognitive coaching. And then I was in [city] for a RTI [Response to Intervention] conference (...) so that's what I've been doing for the past two months.

Furthermore, not only did Kristoff act as a role model for being a professional educator by continuously engaging in CPL, he took his learning from CPL back to the school and collaborated with the teachers to help build a collective understanding of new or refined concepts. By acting as a co-learner with the teachers, Kristoff hoped that the teachers would try to implement the new concepts in their teaching practice to help improve

student learning. For instance, during the 2014-2015 school year, “we’re on a continuum of growth by taking on a Universal Design for Learning approach [UDL]. We are also investigating how we can use technology to support our kids” (Kristoff). Also, Kristoff encouraged teachers to modify their pedagogy so that each class was divided as follows: 80% hands-on activities for students and 20% lecture based. Kristoff called this the 80/20 split.

Beyond teachers being encouraged to implement new initiatives stemming from topics that Kristoff engaged in, Kristoff supported teachers in their learning interests that were relevant to the school goals. Kristoff was trying to develop a school culture that encouraged and supported “professional environments for teachers and we value that type of person on our staff” (Kristoff). For instance, Kristoff:

... regularly makes sure they [teachers] are sent all the information about opportunities that are out there. We want to make sure we are giving them information and encouragement. Therefore, we are going to give them courage and say, ‘what can I do to help you? Can I cover your class? Or create time for you? Or something else?’ I’m encouraging ongoing professional learning in everything teachers do. I send out a weekly bulletin, and in that could just be in all things and opportunities are topics we might want to talk about so that the leadership in the building is thinking that way - that it that there's only one way. (Kristoff)

Given this, Kristoff was eager to provide teachers with “‘whatever you need to make this work for you’ (...) If that’s money to support you, material, or resources, or even time, I’ll help you with that” (Kristoff). Notably, the teachers agreed and were well aware of the fact that Kristoff encouraged and supported their CPL. For instance, Anna and Belle said:

When I signed up for the [science CPL opportunity], I didn’t know if being away from the class once a month was going to work. He [Kristoff] was very supportive of that and said ‘it would be a great opportunity for you, it would be great for the kids and let us worry about the other issues’. So I think he was supportive. (Anna)

I do think he is supportive in terms of collaboration. He has given us common preparation time. So our schedules are okay so we can collaborate. If we said we need this to collaborate, we would get what we want. If we need a half day or we need this, we would get it. (Belle)

A specific example of Kristoff supporting teachers CPL is when Elsa and Belle were involved in a science learning activity held by the local board of education, and they needed materials to apply their learning to their classroom practice. Kristoff was pleased with their initiative to take part in this voluntary and self-initiated activity because “we want that all the time, all the time” (Kristoff). Kristoff expressed his support in the following way when Elsa and Belle requested additional resources:

They [Elsa and Belle] would get two class sets each with whatever materials, but they need two more and asked if I would buy them. I’m going, *absolutely!* I’m going to support you with that! That’s the kind of things we want teachers to do. Here we have teachers who want to promote and get ahead, and try something out and the simplest thing they need is a class set so they can run that unit or idea. Absolutely we are going to support them doing that. And they already knew the answer before they asked question. (Kristoff)

Kristoff’s bottom-up leadership style. Considering that Kristoff “put a lot on everyone’s [teachers] plate, hard” (Kristoff) in terms of being on a continuum of growth during the 2014-2015 year (UDL, use of technology, 80/20 split), he recognized the need to create a balance for “getting what you think is best for the kids and recognizing not to overload teachers either” (Kristoff). Given this, Kristoff facilitated a bottom-up leadership style: he did not mandate teacher participation in CPL beyond board-directed professional activity days and staff meetings that were included in teachers’ Collective Agreement, and learning how to teach using the UDL framework, integrating technology and the 80/20 split in their teaching.

An example of Kristoff implementing a bottom-up leadership style was with regards to him making an executive decision to make teacher release days optional. Release days were described as three half-days, or 1.5 days, allocated to each teacher for “professional development in the area networking or working on something that comes under the umbrella of the school improvement plan or school goals” (Kristoff). The money for release days was provided to Kristoff from the local school board. Given that teachers were on a continuum of growth, Kristoff “decided that release days were strictly driven by teacher choice - if you want the time, it is there, but that's not me going ‘okay science is a really big deal’ because that doesn't work” (Kristoff). The advantage of providing teachers with the choice is captured in the following quote: “those activities are

driven by what they're interested in and me saying, 'yeah I totally support that, what can I do to help?'" (Kristoff). The only caveat to this type of leadership was that whatever teachers decided to engage in, it was supposed to "match what's on our school improvement plan for this year" (Kristoff). This was problematic for teacher CPL related to science because the school improvement plan was aligned with the board plan, and science education was not a predominate subject within those plans. Thus, science was not the focus of teacher CPL within the school.

Kristoff's bottom-up leadership style was valued by the Anna, Elsa, and Belle because they "don't think it [CPL] works well if you are just told what to do" (Belle). However, whether teachers took advantage of the CPL opportunity varied from teacher to teacher. For instance, Anna was "involved in so much PD, she may not have done it [taken the 1.5 release day] because she was away so much for other things she was already doing" (Kristoff) such as being on the Science Task Force, which was a monthly commitment. On the other hand, Elsa and Belle used all of their release time plus additional time to learn about how to implement UDL. Kristoff explained that Elsa and Belle

... spent more money than any other teacher. Theirs was the Google classroom and knowing our students like UDL and how do we plan and organize and group. And they looked at the kids struggling and how we can provide for them in the RTI model. They also did some work with [secondary school] teachers about teaching science. But they got tons of money because nobody else was wanted it. So I'm going, 'I'm going to spend it on you guys because at least you're interested'. (Kristoff)

Anna, Elsa, and Belle were highly active in their CPL, and Kristoff was able to provide them with additional funding to support it because not all teachers choose to use their allocated funds for release days. Overall, Kristoff's bottom-up leadership helped to encourage and support teachers' perceptions of ownership over their engagement in CPL. Lastly, when Anna, Elsa, and Belle choose the activity to engage in for CPL, they were more likely to learn from it as it was relevant to their teaching and learning needs.

Supportive Structures: Internal to the School

Kristoff developed an internal support system to help facilitate teacher CPL for all subjects, not specifically for science education. Kristoff explained that the schedule was developed to help encourage teachers to engage in collaborative activities that included problem-solving, instructional improvement, co-planning, co-teaching, developing assessments and marking together, and reflecting on their teaching practice and student learning. However, it was the choice of the teachers as to whether they discussed science education or other subjects. The two internal support systems were:

1. *Academic Teams*. The organization of the school revolved around academic teams. There are three primary components of academic teams that were created to help facilitate teacher CPL: (a) common teaching schedules, (b) curriculum books, and (c) same grade classrooms being grouped near one another because the large size of the school.
2. *Reflection Day*. Reflection Day, a pseudonym for the purpose of this study, was implemented in the master teaching schedule to encourage teacher collaboration and to help solidify student learning by encouraging teachers to take the time to focus on student learning needs without having to teach new material.

Following the discussion about the two initiatives, the teachers' perceptions about why they still felt isolated in relation to their CPL related to science is presented.

Academic Teams. Kristoff created academic teams to encourage every teacher to adopt the mindset that they were not isolated bodies of knowledge disseminators for their students within their private classroom. Rather, they were a team of educators who collaborated to benefit all students learning. Kristoff's goal was to get teachers to "only think team in the building on everything [they] do" (Kristoff). The teams were composed as follows: the Grade 1/2 team had four teachers, the Grade 2/3 team had five teachers, the Grade 4/6 team had six teachers, and the Grade 7/8 team had four teachers. Moreover, "on each team, there is a variety of resources like library, ESL, and support staff" (Kristoff). Kristoff weaved the concept of academic teams into most aspects of the school. For instance, even in "staff meetings or any professional development activities, teachers are required to sit with their academic team. So, if we want to do something that's focused in their area, teachers are doing it amongst their academic team" (Kristoff).

Common teaching schedule. Kristoff created the master schedule so that teachers on each team had the same teaching schedule. Using the example of the Grade 2/3 team that included Anna, all teachers on the team had gym and integrated art subjects during the first block. Then they all taught literacy during the second block, followed by math and science during the last block. Considering that each teacher on the team had common teaching schedules, they also had common preparation time within block one. So, either teachers were off during the same period, or “one teacher’s prep time is before and another teacher’s prep time is after this period so that there is an opportunity to co-teach and co-plan” (Kristoff). Kristoff believed that providing common preparation blocks encouraged and supported a teacher’s ability to engage in collaborative activities including problem-solving, instructional improvement, co-planning, co-teaching, developing assessments and marking together, and reflecting on their teaching practice and student learning.

Curriculum books. Besides having common teaching schedules on an academic team, each team member was provided a curriculum book that included the yearly curriculum for every subject for only the grades within the team. For example, each teacher on the Grade 2/3 team had a copy of the curriculum book composed of each subject requirements for Grades 2 and 3. The purpose of these books was for teachers within a team to be able to “easily pull expectations from math and science, and language or English, too, yet, still meet the demands in the curriculum” (Kristoff). Taking together that teachers were on academic teams had the same preparation blocks, and curriculum book specific to their teaching needs, Kristoff created an internal structure so that teachers had time to engage in collaborative activities during their common preparation time to potentially co-plan lessons and/or assessments, or teaching strategies for example, while easily accessing the curriculum specific to their teaching needs. Kristoff perceived these aspects to be beneficial to the teachers because “there is no way to teach everything. But together, teachers can think about what’s important to focus on within the book” (Kristoff).

Teacher classrooms located beside one another because of the large size of the school. The third aspect about academic teams was that teachers within a team had classrooms that were side by side and/or across from one another “in a specific location

in the building so they are at least with a partner or partners” (Kristoff). The concept of having each team in close proximity was important because the school was so large that if teachers were not in close proximity to one another, they did not collaborate: “this building is not a building where people tend to go to the staff room a lot because it’s out of the way. The size of this school makes a difference” (Belle). Elsa and Belle hardly saw Anna because they were on different academic teams, and their classrooms were located in different sections of the school. Anna was “downstairs in another part of the building so it’s not even like you’re across the hall and we can easily talk to one another” (Belle). The proximity between teachers was important because Elsa and Belle only collaborated if they had a specific question for one another about a concept or a student *and* if it was convenient to collaborate – they did not plan a time to collaborate with one another about science: “It’s always spur of the moment. Usually I run into her classroom or she runs into mine depending on where we are going” (Elsa). Elsa and Belle were on the same academic team and thus, their classrooms were located side by side so they would “bump into each other” (Belle) often – unlike bumping into Anna, which hardly happened. Given this, Elsa and Belle collaborated less often with Anna because Belle is “not sitting there with Anna saying she did this and so did I. We don’t have the same communication” (Belle). So, without Elsa and Belle being in close proximity to Anna within the school, Anna, Elsa and Belle were not in the optional setting to collaborate with one another.

Reflection Day. The second internal structure Kristoff developed to encourage and support teacher CPL within the school was Reflection Day. Kristoff allocated two days within the 10-day teaching cycle to Reflection Day whereby “no new teaching” (Kristoff) was necessary - the solidification of student knowledge was more important than teaching everything in the curriculum. Kristoff wanted to encourage teachers to take the time to reflect on their students’ learning and to see whether concepts needed to be readdressed to better meet the students’ learning needs. Kristoff’s hope was that teachers on an academic team who were also teaching from the same curriculum book would plan for Reflection Day by working “collaboratively over the curriculum and decide as a team what they are going to teach” (Kristoff). Included in this planning was reviewing student data and needs. Considering that teachers could teach the same or similar lessons, they

could also create similar assessments and collaborate while marking as assessing student achievement.

In line with Kristoff's bottom-up leadership style, he did not mandate teachers to implement Reflection Day, nor did he tell them "what must happen on these days because then I would be mandating what is to happen" (Kristoff). By letting teachers figure it out for themselves, Kristoff said that teachers "started sharing ideas and collaboratively working together. Teachers were observing each other and learning from one another". From the perspective of the teachers, Anna, Elsa, and Belle spoke about how they "don't always do my Reflection Day on day 5 and 10 [as it is planned in the timetable]. I do it when it works for my students" (Belle). Elsa explained that she may be "two days into a lesson and obviously need to review. I'm thinking more math, but sometimes you need a Reflection Day before, or sometimes class is going well so you don't need to take a reflection day so soon". Anna said that she takes a Reflection Day whenever she feels it is needed because she does not want to wait until a designated Reflection Day "to tell them [the students] they are doing it incorrectly - like a math concept. I do it when necessary for everyone to catch up, recruit, and figure out who needs what".

Time limited teacher engagement in CPL regardless of the internal support system. Teachers expressed that regardless of being on academic teams and having Reflection Day, their collaboration for science was limited because of three reasons that each stemmed from a lack of time. First, Anna, Elsa, and Belle were generalist or classroom elementary teachers; not only did they prepare for science, they were responsible for preparing for math, language arts, social sciences, history, and all other subjects that affected the amount of time they were able to designate to their science collaboration. From Anna, Elsa, and Belle's perspective, although they had common timetables and preparation time, they explained that their preparation time was "all math and language focused" (Anna). Anna continued to express that she received "tons of things but it's language related. There is really no time I feel for science – to sit down and work with others and talk about science. We will talk about math and language but not science". As Elsa said: "when you are spread thin on other subjects, science isn't the main priority". Anna agreed and noted that "because of being a classroom teacher, you

have to cover everything. So it's yeah, it is time, still considering that you need to do language, math, art and whatever else”. Lastly, Belle said:

I have to get all of these things ready for science class, and I have to photocopy this for math, I've got to do this, and this, and this. The one downfall with elementary is that I'm torn in so many different directions. I'd love to do a great job on the science lesson but I still have to plan for language and something else too, and mark this, this, and this. (Belle)

Kristoff's comment: "science is the least of people's worries today", may be a reason as to why the teachers do not have sufficient time to focus on science during their common preparation blocks, although they are on academic teams and have Reflection Day.

Secondly, Anna, Elsa, and Belle were new teachers at the school and perceived that the length of time they taught at the school influenced their collaboration. It was Anna's first year, and Elsa and Belle's second year teaching at the school so they were only beginning to be comfortable within the school environment. The teachers expressed that they needed time to become familiar with the students and their learning patterns, and to build a collaborative working relationship with other teachers who taught, or are teaching the same students. The time to build relationships was necessary because Anna, Elsa, and Belle's engagement in collaborative activities were not planned; they occurred when a pertinent issue arose with particular students, and then they would collaborate when it was convenient. To engage in such collaboration, the teachers needed to feel comfortable to spontaneously engage with a fellow teacher. Anna, Elsa, and Belle expressed their views in the following way:

It was both our [Elsa and Belle] first year here and we were getting comfortable. There is a lot more collaboration going on this year even though we are teaching different curriculums. I sometimes ask Belle about some specific students she had last year because I'm teaching lot of the kids she had last year. So that's where I go back and talk to Belle. Or I'll go back and say they aren't understanding this. Clearly this assignment shows that they didn't understand it so I may ask Belle for advice. (Elsa)

I think you have to find out who you are comfortable with. I think a lot of collaboration is with who you are comfortable with. Elsa and I got to know each other last year so we are much more likely to work together this year than last year. If something comes up, I'll go 'oh I didn't expect that from that person'. But Elsa talks to me because I taught the students last year. So it's more someone who knows the students who I go to. Like, Elsa hasn't generally taught my Grade 7

science students or I don't generally go unless it's a student who she has in her homeroom. If I wanted that, I would go to someone who knew the student. (Belle)

Thirdly, Anna, Elsa, and Belle perceived their collaboration for science to be limited due to the inadequate number of available teaching partners within and across academic teams. Moreover, their collaboration was further limited to teachers who shared similar teaching styles – inquiry-based and applied the DRiVe model – for science teaching (see Chapter IV for a description of the DRiVe model). Although Elsa and Belle were on the same academic team, shared the same curriculum book, had classrooms side-by-side, and they collaborated about science when needed, Belle felt “a bit isolated in science” because there was a lack of different “people in the building to collaborate with” (Belle). Belle emphasized that she and Elsa were the only teachers teaching science on the intermediate division academic team. Given this, there were a limited number of teachers to collaborate with about science as compared to “language because there are four teachers teaching Grade 7-8 language. So, we are always bouncing something off because there are three other people here who do the same thing or similar things” (Belle). Also, Anna was hesitant to collaborate with other teachers on the Grade 2/3 academic team - all of whom taught science - because they did not teach science using the DRiVe model; they taught with traditional pedagogy instead of reformed, inquiry-based pedagogy. From Anna's perspective, “everyone has to be on the same page or willing to turn their page”. Anna continued to explain:

You also don't want to go in with ‘this is what I do’ attitude because everyone does things differently. So you do have to feel it out and figure out who you can work well with. (Anna)

Anna, Elsa, and Belle also added that learning about the instructional strategies that other teachers employed in their classroom was also a matter of having the time to learn about the other teachers. Kristoff acknowledged that although teachers were on academic teams to strengthen and enhance their ongoing collaboration, “there are people on different places on the continuum of planning from a team perspective versus doing it on your own” (Kristoff) for reasons that include various teaching styles.

Supportive Structures: External to the School

Kristoff promoted teacher engagement in CPL within and out of the school environment. However, similarly to the limited CPL about science within the school, Kristoff, Anna, Elsa, and Belle expressed that CPL opportunities related to science were not offered out of the school in great abundance. Three CPL opportunities related to science were discussed: (a) Grade 4-10 Transitions and Pathways Collaborative Inquiry, (b) the Science Task Force, and (c) Sector Projects. Below is a description of each opportunity. Following is a discussion about how the Anna, Elsa, and Belle valued the designated time for science learning, coupled with two characteristics of the external CPL opportunities that Anna, Elsa, Belle, and Kristoff believed were beneficial to the teachers' learning: (a) like-minded science educators, and (b) science coaches.

Grade 4-10 Transitions and Pathways Collaborative Inquiry. The Grade 4-10 Transitions and Pathways Collaborative Inquiry project was hosted by the Student Achievement Division from the Ontario Ministry of Education. It was meant to “support boards in addressing the transitions in student’s lives that affect achievement and well-being and how, through collaborative inquiry, we can support and change the outcomes of these students” (Ontario Ministry of Education, Student Division, p. 1). Prior to initiating this research study, Kristoff applied to the local school board to receive funding for Anna, Elsa, and Belle to take part in this project specifically about science because Kristoff was aware that Anna, Elsa, and Belle were “worried about whether they covered the things they need to cover. Also, how they can creatively deliver the curriculum so that it is really good for the students” (Kristoff). Thus, the goals were for Anna, Elsa, and Belle to collaborate with teachers from a nearby high school teaching Grade 9 and 10 science, and learn about how to better prepare students “for a good transition from elementary to secondary” (Kristoff). Kristoff used the allocated funds from this project to release the teachers from their classroom duties to engage with one another and with the secondary teachers.

Belle explained that they met with the “high school teachers at [a secondary school] and asked them what they wanted students to know in science for entering Grade 9”. The result of this collaboration was that Anna, Elsa, and Belle learned the importance of teaching using the DRiVe model: “the secondary teachers want students with good

science skills” (Kristoff). The secondary teachers were not concerned about the elementary student’s science content knowledge. Rather they “wanted students to know variables, they wanted them to know the DRiVe model, how to write lab reports, and they wanted them to know how to graph” (Belle). So, Anna, Elsa, and Belle learned that they needed to alter their teaching to focus more so on teaching inquiry skills using the DRiVe model as opposed to focusing on everything in the science curriculum related to science content knowledge: “the process is more important than the content. I have learned to focus more on the big ideas and not to worry about every curriculum expectation” (Belle). As a result, Anna, Elsa, and Belle tried to better prepare their students for high school by modifying their science teaching to help ensure that their students completed elementary school “knowing how to actually complete a lab, how to think out of the box and how to do inquiry” (Elsa). A specific example of Elsa and Belle modifying their teaching is when they adapted a science experiment worksheet using the DRiVe model to better prepare students for what they will do in high school science: “Belle adapted it more because she teaches Grade 7 and mine looks more like the [high school]” (Elsa) because Elsa taught Grade 8. Based on this project, when planning for science, Elsa and Belle considered the curriculum and what needed to be taught first, and then “veers off at some point” (Belle) to focus on inquiry-based skills. For instance, if something is not included in the curriculum but it is inquiry-based and “students are interested then we go in that direction. As long as we talked about them knowing variables and lab reports and I incorporate that. Then I go ahead” (Belle) because Belle understood what is necessary of her students upon entering high school. Compared to Elsa and Belle, Anna did not modify her science teaching as much because she did not feel as much pressure about curriculum expectations for the reason that she perceived the science topics from year to year were not followed up the following year due to the way the curriculum was created. Also, Anna was already applying inquiry teaching using the DRiVe model for her science units. For instance, she said: “I’m focused on the inquiry skills and the thinking skills. You have to get the curriculum in there because you have to report on it. But at the end of the day there is no continuation to the next year” (Anna).

Science Task Force and Sector Projects. The Science Task Force and the Sector Projects were funded and facilitated by the school board. With the support and

encouragement from Kristoff to engage in such activities, Anna, Elsa, and Belle took the initiative and volunteered to participate in either the Science Task Force or Sector Projects to further their science teaching using the DRiVe model.

Anna joined the Science Task Force in 2014. It was a once a month commitment for a full day. Being on the Science Task Force provided her with the “opportunity to work with others, ask questions and develop a deeper understanding of content, resources, and big ideas to bring back to the classroom and teach” (Anna). Anna emphasized that she enjoyed participating in the Science Task Force because:

You always come back with something else to do. Something that, for me, I never would have thought to have students making a catapult to teach forces and how to make it. I wouldn't have known that if I didn't go to the Science Task Force.
(Anna)

On the other hand, Elsa and Belle did not join the Science Task Force because it was only available to primary and junior grades so they participated in Sector Projects that were targeted to Grade 7 and 8 science teachers. The Sector Projects had science related themes that integrated other components of the curriculum such as numeracy and literacy. Specific projects were provided during various months throughout the school year for teachers to learn about an investigation that they could conduct with their class that was related to their teaching grade and curriculum demands. Elsa and Belle both complete two projects: Trebuchets and Putt Putt Boats.

The Science Task Force and Sector Projects were helpful because they were “all about teaching using DRiVe” (Elsa) and taught the teachers about specific inquiry-based investigations that they could immediately apply in their classroom because they were directly related to their teaching grade. Also, participating in the out-of-school CPL activities related to science education provided Anna, Elsa, and Belle designated time to focus on bettering their classroom practice and knowledge specifically about science. This time was valuable because as previously discussed, Anna, Elsa, and Belle's preparation time within the school was primarily dedicated to numeracy and literacy. Overall, Anna, Elsa, and Belle agreed that their participation in the activities improved their science teaching because they learned hands-on “activities that would help students understand [science] concepts” (Elsa). There were two specific reasons why Anna, Elsa,

and Belle perceived an improvement to their science teaching practice from participating in the three CPL activities related to science discussed above. First, Anna, Elsa, and Belle had scheduled time to interact with several like-minded science educators who were also receptive to focusing only on learning hands-on investigations for science. Secondly, during the activities, Anna, Elsa, and Belle appreciated learning with the help of science coaches.

Learning with a group of like-minded elementary teachers teaching science.

While engaging in the Science Task Force and the Sector Projects, Anna, Elsa, and Belle interacted with a group of like-minded elementary teachers teaching science to grades within the same division (primary or intermediate). With a larger group, the teachers were able to learn from one another given that each teacher had different perspectives about conducting experiments or about science education in general. Elsa and Belle expressed their view in the following ways:

I like the wider network because you meet with other teachers and get more ideas because [Belle] and I share all the time. We [Elsa and Belle] make a DRiVe out of our ideas and we think the same way eventually and we may not have new things to share. But going outside, having that day for PD, just focusing on science, is great because [in school] we also talk about science, but we also talk about kids, we also talk about math, and literacy; we talk about everything. It's not just science and so having that one day to focus on science, I think is really helpful. (Elsa)

It's good in Sector Projects with people in the same grade. You go, 'oh, I didn't think about doing it that way' or that's how you set that up, or you took it and did this with it. It's good to hear what other people do with same experiment. (Belle)

Science coaches and the implications on Anna, Elsa, and Belle's learning.

Anna, Elsa, and Belle valued having a science coach teach them hands-on investigations. The coaches first modelled the necessary inquiry skills that were related to what teachers were or would be teaching to their students according to what was required in the curriculum. Then, teachers would practice conducting the investigation while having the science coach address specific questions and concerns that they had. Given this, when the teachers attended the out-of-school CPL activities, they engaged in the learning process whereby they conducted the inquiry-based investigation as a learner. The concept of having a science coach was favorable as Belle explained: "I want to be shown! I can read

about it all I want but I want it to be shown to me. Show me how to adapt it to what I may have at my school”. Belle also highlighted that she preferred having a science coach because the person taught them how to use equipment, how it works, and how to set it up. So, having a science coach was deemed integral to their learning because CPL was “one of those things that if it’s not geared toward people then people aren’t going to be interested in it” (Anna).

Kristoff was equally enthusiastic about Anna, Elsa, and Belle participating in the science activities that involved science coaches because “from an educational or academic point of view, coaching is everything”. However, Kristoff pointed out that after Anna, Elsa, and Belle engaged in the investigation with a coach, they were not provided the time to reflect and analyse their learning outcomes with a science coach - the coaching only happened during the out-of-school CPL activity as it was not extended to the daily work environment within the school. So there were two problems that arose: first, there was a lack of time for teacher reflection, and secondly, there was a lack of fiscal resources to hire a science coach to be regularly in the school environment. Kristoff believed this as problematic because teachers need time to reflect on an ongoing basis to reinforce their learning with a science coach: “the most important piece of collaboration is the last part – reflection time. You have to have time for that. So, teachers need to figure out when they collaborate to also reflect. That’s a huge piece” (Kristoff). Kristoff emphasized the reflective aspect because it provides time for teachers to engage in inquiry-based discussions, and reformulate and solidify their understanding of teaching and learning a concept, which ultimately helps to improve student learning. Kristoff’s concluding remark about science coaches and reflection was that for coaching to be effective and transform teacher’s science practice, it “has to be ongoing. It can’t be, ‘I’ve been coached today, isn’t that exciting! Wow!’ No. It has to be ongoing coaching” so that teachers could engage in “co-planning, co-teaching, coaching, and there is always comeback time to reflect on how are things going and what we are doing next” (Kristoff). Otherwise, Kristoff said that what teachers learned with the coach may not have transformed their teaching practice as much as it could have.

Theme 2. Teacher's ability to engage in, and learn from in-situ CPL related to science was limited by factors stemming from the Ontario education system and local school board. Mitigating the issues includes placing equal emphasis on all subjects in Ontario's elementary education and redistributing time and fiscal resources to regularly include science coaches in the school environment.

Kristoff, Anna, Elsa, and Belle offered their thoughts on two domains representing the challenges and tensions. Below is a brief outline of the issues that are discussed in further detail throughout Theme 2:

Ontario education system

1. Regarding the Ontario science curriculum, Kristoff held differing opinions than Anna, Elsa, and Belle about whether the curriculum was disconnected between grades and whether it helped facilitate or hinder teacher collaboration.
2. The Ontario education system placed more emphasis on numeracy and literacy than other subjects such as science education.

School board

3. The time available for CPL related to science within the school day was limited by facets included in the teachers' Collective Agreement: preparation time, staff meetings, and professional activity days (sometimes referred to as PD Days by the participants).
4. Fiscal resources limited ongoing CPL in science. Limited funds: (a) may have influenced a teacher's choice to select science as a topic to study for their release days, (b) hindered ongoing learning, and (c) hindered teachers' collaborative use of student data to address student-specific learning needs.

Following is a discussion about how Kristoff presented possible resolutions to the dilemma of limited time and money for teacher collaboration related to science by posing the redistribution of time and money to include science coaches within the school environment to assist the teachers on demand and according to their needs with their students.

Ontario's Education System Limits Teacher CPL with regards to Science Education

Ontario's Science Curriculum. Kristoff held different beliefs than Anna, Elsa, and Belle about whether the science curriculum was a limiting factor to teacher's in-situ CPL related to science. Anna, Elsa, and Belle expressed that a barrier to their CPL within the school environment was the science curriculum because it was perceived to be disconnected between grades. For instance, Elsa said: the science curriculum "varies by topic every year in elementary school so professional learning is limited. I feel like we can still collaborate but I'm still teaching cells and forces while you [Belle] are teaching ecosystems and heat". The result of this perceived disconnect in the science curriculum was that Elsa and Belle did not collaborate often: "I don't feel we use it [CPL] as much as we could in science. Maybe if we were both teaching Grade 7 and Grade 8, then we would more so take ideas from one another" (Belle). Anna also highlighted that considering she perceived the science curriculum to be disconnected between grades, collaborating across grades was not useful because if she could not report on a topic outside of Grade 2/3, there was no point teaching or spending time to collaborate on a lesson. Anna explained: "if you are doing that [collaborating] and it's not Grade 2/3 curriculum, you can't report on it. If you can't report on it, how much time do you want to spend collaborating?" Ultimately, "I'm not going to do it because the curriculum doesn't say that is what I should do for that year. You are limited by what you need to teach". On the other hand, Kristoff did not believe the curriculum was a limitation to teachers engaging in in-situ CPL related to science. Rather, he believed that teachers lacked the instructional repertoire to be able to teach "big ideas" that spanned the curriculum across grades. When referring to big ideas in the Ontario 2007 revised science and technology curriculum, they are the "fundamental concepts that are addressed at each grade level. Developing a deeper understanding of the big ideas requires students to understand basic concepts, develop inquiry and problem-solving skills, and connect these concepts and skills to the world beyond the classroom" (p. 6). He expressed his view as follows:

Is it the knowledge of the curriculum that must be taught getting in the way? Or, is it the teachers going, I have to teach that curriculum so I have to do this verses, I don't have the teaching skills to teach in a way that's totally inquiry-based and

focused on teaching the big ideas? Which one of the things are getting in the way? Well, no doubt teaching is. (Kristoff)

Regardless of the difference in beliefs about the impact of the curriculum, Anna, Elsa, Belle, and Kristoff agreed that the primary focus of the teacher collaboration should have, and was on the specific learning needs of their students and what the teachers needed to do to help those students learn. From the perspective of Kristoff, the science “curriculum is secondary”. Teachers “can talk about pedagogy, talk about student learning, and materials to make that happen? Yes, and that’s what you want them talking about” (Kristoff). Essentially, teacher collaboration should be “a dialogue about learning. We are looking at student learning” (Kristoff). Anna, Elsa, and Belle were thinking similarly. For instance, Belle and Anna agreed with Elsa when she said: “that’s what the collaboration is - to tailor a lesson to my kids. How can I do it with this group of kids? It’s very specific and tailed to my kids”.

Placing equal value on all subjects in Ontario’s education system. Kristoff, Anna, Elsa, and Belle mentioned that the limited CPL opportunities in science were not because science was not important or valued. Rather, that CPL for numeracy and literacy took precedence— that is where the financial resources and time were allocated. Kristoff highlighted that “it’s not so much that science is the least of educator’s worries – but with so much focus on literacy and numeracy, and scores, then everything else comes second or third” (Kristoff). This concept of subjects coming first, second, third and so on is what Kristoff wanted to change: he wanted to change the structure of the Ontario education system to eliminate the “waves” of predominate subjects to begin placing equal emphasis on every subject. To explain the waves, Kristoff commented:

For a long time, it was literacy, literacy, and literacy. Then oh shoot, the math scores are down. So now we have to spend all our time on math. Now all initiatives coming out the ministry and board is in math and the Collaborative Inquiry for Learning: Mathematics initiative. Until we think differently about science, and no doubt we should be, I don't know if that concept will change or not. When I visit with other principals, I don't hear anybody going ‘oh my gosh, this is a really cool science thing we are doing’. (Kristoff)

Given this, “we can’t put one subject is first and another second. Education has to be looked at differently. Otherwise, students get better at reading and get worse at science”

(Kristoff). Anna, Elsa, and Belle agreed with Kristoff's opinion about placing more predominance of numeracy and literacy than science. For instance, Anna said: science is "definitely behind language and math. There isn't a lot of science professional development mentioned outside of this [research study]. It was all literacy, math, and even art. You could get art professional development before science professional development". Or, as Elsa said: "language and math come first and second by far" (Elsa). So, teachers "take whatever I can get" (Belle) for science professional learning.

Teachers also explained that science gets pushed behind numeracy and literacy because "every time we turn around, there are mandates coming from the ministry or board saying teachers should be emphasising this, this, and this" (Anna). This creates a problem for teachers as they are overloaded with meeting accountability demands in literacy and numeracy resulting in limited time to focus on science. Teachers said that their overloaded work load was the greatest inhibitor to effectively teaching science. Belle also explained that there was no push from the ministry or local board to have teachers modify their teaching to implement the DRiVe model in science:

I don't think there is the emphasis on science. We [Anna, Elsa, Belle] know the DRiVe model because we have gone out and pursued it. But there has not been an emphasis on pursuing the DRiVe model that I've seen. I could be wrong because I've only looked at science for the past couple years. But I don't think there is a push at any level to have teachers change their science teaching. Like there is no push across the entire school saying, you need to teach science this way. I don't see that. (Belle)

Kristoff also agreed that there was a lack of push for science education, and for teachers to implement the DRiVe model in their teaching. As such, Kristoff shed light on the fact that unless drastic changes are made to Ontario's education system, the wave of education will continue to be a perpetual problem. Although, Kristoff greatly acknowledged that although the Ontario education system needs to change "that's not easy to do – it's scary" (Kristoff). It would require thinking about "education differently - where it is a little more embedded, a little more integrated and you're pulling from a variety of different subject areas" (Kristoff) so that equal value is placed on all subjects. The reason for Kristoff proposing this drastic change stems from the question, "why isn't science an issue in elementary school?" (Kristoff) In the Ontario context? On global

assessments, “science is one of the measures, but we are not doing anything about it. Maybe we are but not necessarily. It hasn’t got a singular focus like math and literacy” (Kristoff). The teachers agreed that the way to make science more predominate in Ontario’s education was to make science part of the standardized tests such as EQAO: “so I think it would take some sort of testing where they compare student results across the board” (Elsa).

School Board

Teachers’ Collective Agreement limits time available. The teachers and Kristoff had polarizing opinions about the Collective Agreement and its impact on teacher CPL. Anna, Elsa, and Belle perceived that the Collective Agreement was *not* a limitation, whereas Kristoff emphasized that it was his greatest limitation. The Collective Agreement was a burden for Kristoff as it was his responsibility to create time for teacher CPL through purposeful timetabling and distributing limited fiscal resources. Kristoff believed that it is “all about Collective Agreements right now and it’s always getting in your way” (Kristoff). Briefly, the Collective Agreement for teachers is a legally binding document that outlines conditions of employment with Kristoff at the elementary school. Both parties must agree to follow the outlined conditions: salary, benefits, working conditions such as preparation time, supervision time and sick days. Below, the perspectives of Kristoff, Anna, Elsa, and Belle about teacher engagement in CPL related to temporal factors stemming from the Collective Agreement are discussed. The three main topics are: (a) preparation time, (b) staff meetings, and (c) PD Days.

Preparation time. As discussed in Theme 1 under the section titled “common teaching schedule”, Kristoff created timetables so that teachers on the same academic team had the same teaching schedule, which also included having common preparation blocks. Regardless of teachers having their preparation breaks during the same period or one after another in the same block, Kristoff’s ability to encourage teachers to collaborate (co-planning, co-teaching, designing assessments, etc.) during their preparation time was limited because he could only “organize the time however I want” on the condition that teachers had “480 minutes of preparation time during a 10-day cycle as stated in the Collective Agreement” (Kristoff). However, “how teachers collaborate and how they use that time is up to the teachers. I can’t dictate how that time is used” (Kristoff). Given this,

whether teachers choose to use that time to collaborate about science was entirely their discretion. Anna, Elsa, and Belle expressed that most often, their preparation time was not dedicated to science. For instance, Anna said:

Even though we have common prep. times, we are all doing our own different thing. Or it's language. A lot of the time I get handed tons of things, but it's language related. So there is really no time I feel for science – to sit down and work with others and talk about science. We will talk about math and language but not necessarily science. If I need more time it has to come from science because it can't be math or language. Social studies already gets a backburner. (Anna)

Staff meetings. According to the Collective Agreement, staff meetings were held once a month for a total of 90 minutes: “there is a beginning and an end to the meetings. The beginning needs to start at a certain time, and you have 90 minutes after that for a staff meeting” (Kristoff). Because Kristoff encouraged and supported CPL within the school environment, he had to plan how to include time for teachers CPL during staff meetings. Besides having teachers sit amongst their academic team, Kristoff tried to designate time in each meeting to CPL. However, “it is hard all the time because there is a lot of information that needs to be dealt with face-to-face. Or sometimes there are presentations. But I try to create some of the time for collaboration within those meetings” (Kristoff). Moreover, the time for collaboration that Kristoff could designate during the staff meetings was also not designated to science education.

Professional Activity Days. The third aspect of the Collective Agreement that limited the time available for teacher CPL related to science were the professional activity days. As a reminder, according to the Ontario education act (1990), regulation 304, professional activity days are opportunities for teachers to engage in professional activities during the school day on the school calendar. Under the Collective Agreement, Kristoff explained that there were a total of six professional activity days for the 2014-2015 school year: three of which were used for professional learning while the remainder were used for activities such as writing report cards, teacher-parent interview day, or preparing for the following school year. So, “the three that we have, we try to make valuable. But science isn't the only thing on the on the menu” (Kristoff).

From the perspective of the teachers, Anna, Elsa, and Belle thought that the professional activity days were geared toward numeracy and literacy for the purpose of reaching the desired outcomes determined by the Numeracy and Literacy Secretariat on standardized tests such as the Education Quality and Accountability Office's tests. Also, Belle explained that science is not a topic that could be generalizable to all teachers because not all teachers teach science. So, the days "in the school, we are doing technology or school effectiveness, or goal setting" (Belle). Consequently, each teacher said that professional activity days were not helpful to their science learning or learning in general: they were "not teacher based or what would help you in the classroom" (Elsa). Or, as Anna said: "I don't feel like they help *me* in *my* classroom". The professional activity days were not helpful to the teachers because they needed to be geared toward what teachers were interested in and motivated to learn, which was always changing. For instance:

Some years I'm very comfortable with what I'm doing in language or another year I'll want to know more about something completely different. This year I'm teaching science for only the second year. I've never signed up for a science workshop, so I need to sign up for something related to science. (Belle)

The second aspect to the three professional activity days used for professional learning was that they were so few and far between (September 2014, April 2015, and June 2015) that even if Kristoff was able to incorporate science as a theme during one, two, or all of the professional activity days, "continuous learning isn't happening on PD days" (Kristoff). Not only was teacher learning not ongoing after the professional activity days, there was no designated time for teachers to reflect on what they learned after each professional activity days. So, Kristoff believed that whatever teachers may have learned or understood was likely not solidified, reflected on, and put into practice. As such, Kristoff questioned how it was possible to follow-up with learning from professional activity days when there was no "comeback time" for reflection because of the limited time available.

Limited Fiscal Resources Inhibited Teachers Ongoing CPL in Science. When Kristoff, Anna, Elsa, and Belle spoke about limited fiscal resources, it was highly intertwined with the concept of time, but I separated the two constructs for the purpose of

teasing out factors influencing teacher engagement in CPL related to science. Below is a discussion about three domains of CPL related to science education that were affected by fiscal limitations: (a) release days, (b) teachers ongoing professional learning, and (c) the ability to analyze student data while collaborating.

First, the local school board provides each school with money to support the three half-days or 1.5 release days for teacher professional learning. The issue was that the “money [for release days] comes in envelopes from the board, and one doesn’t come specifically for science” (Kristoff). As a brief reminder, “teachers got to pick specific generic topics they wanted work on for the three half days they had released” (Kristoff) because of Kristoff’s bottom-up leadership approach (discussed in Theme 1). However, Kristoff expressed that none of the teachers chose to focus on science, possibly because there was only a “short window of time and money for X number of release days (...) So, that could be one issue why teachers did not specifically choose to focus on science – they had the choice to focus on other subjects” such as numeracy and literacy that were more prevalent in the education system.

The second issue with having limited money for release days was the aspect of continual learning. Even if Kristoff wanted teachers to engage in release day activities that revolved around science and the inquiry process, and “‘we will all do an inquiry in the building, and it is ultimately science related’ (the fact is that) continuous learning isn’t happening on release days”. Kristoff explained that “unless you’re provided with money, or you got teachers who can work outside of school time, then how do you continue that? Reality is, you don’t”. This is problematic because teacher CPL needs to be ongoing so they can co-plan, co-teach, reflect, and re-teach lessons based on their new understandings from their reflection. To make time for ongoing learning, time needs to be included in the teachers’ Collective Agreement.

Thirdly, the ability for teachers to collaboratively review student data for science was limited by fiscal resources. Analyzing student data during teachers’ engagement in CPL was not common practice for science education: “as much as the concept of student data driving teachers teaching makes sense, it just isn’t a science thing” (Kristoff). The main reason was due to the emphasis on spending fiscal resources on literacy and numeracy achievement. For instance, every six weeks, Kristoff provided the primary

teachers with additional release time to address student data for the purpose of co-planning and co-teaching, and “explicit teaching using guided reading in Grade 1 to Grade 3-4” (Kristoff). The teachers analyzed student data in literacy to “make decisions to move kids, adjust or add more intensive intervention by noticing what they need. Or if they don’t get a particular comprehension strategy how can we teach in a different way?” (Kristoff) However, this initiative was only for literacy in the primary grades. The reason Kristoff provided was:

This program every six weeks is a costly intervention because I'm paying for two supply teachers every time we do that. I don't have an endless budget! But, this is so important. So our money is allocated based on me saying this is important. Would it be nice to do this for science and every subject? Absolutely! (Kristoff)

The above discussion was primarily related to primary teachers. Belle, one of the intermediate teachers, stated that she did not collaborate using student data in science: “I’ve done it for language but not science”. Elsa also agreed with Belle’s statement.

Redistributing Time and Fiscal Resources. Kristoff firmly believed in the benefits of CPL for teachers, students, and the overall school improvement: “we know that collaborative professional learning is a big deal - it works. We’ve seen it work! Theoretically it works, you don't have to go too far to know that - whether it's PLCs or Communities of Practice” (Kristoff). So, CPL needs to be scheduled in a teacher’s timetable “every 10 or 5 days, or part of a weekly schedule” (Kristoff) considering the known benefits. Kristoff expressed that time and money could be rearranged from components of teachers’ Collective Agreement - professional activity days, release days, and preparation time - so that teachers can have time within the school day and within their place of practice for CPL with the assistance of a science coach on an ongoing basis. However, to have science coaches within the school, Kristoff expressed the need to redistribute the way in which time and fiscal resources were allocated.

First, according to Kristoff, “we may as well take that 1 ½ release day money and do something better. Not that it isn’t valuable, but can we do something better” – have science coaches within the school working with a team of science teachers, for example. Secondly, in terms of preparation time, Kristoff explained that instead of having 480 minutes of teacher preparation time within a 10-day cycle, reduce the time to 30 minutes

a day for example, which would cut the cost of preparation time. Then, use the money saved from reducing preparation time to have full-time, subject specific coaches (otherwise called a curriculum teacher) in the school building to help the teachers with their specific needs, on demand, and within the school day. Also, the subject coaches could engage in classroom activities with the classroom teachers. In this sense, teachers would have time to engage with subject specific coaches, including science coaches, based on their needs with their students, using the resources that they already have.

Kristoff explained that this example was a model that he preferred and was based on what he learned when he was engaged in a CPL activity:

When I was in [province], teachers have 30 minutes of prep time a day. But they also have three curriculum teachers in the building who are on top of the classroom teachers, and they are also not Spec. Ed teachers. So what if one of those teachers was science and they worked with the teachers and kids on science? That's the only job they have across the school. But that's how they spend their money. So they value this and this subject, and we are going to support this and this with people. That is a wicked model. (Kristoff)

Essentially, Kristoff said that to get the best “bang for your buck, PD needs to be ongoing, and coaching needs to be part of that. The expert comes here [to the school], works with your team here, and then you always have comeback time – learning is ongoing”. Thus, the inclusion of science coaches would help tailor teacher's science learning to their specific learning needs, have the advantage of learning instructional practices using the resources already available and within their school of practice, and ultimately, teachers would learn how to facilitate science investigations that are relevant to their specific students learning needs. Furthermore, it was Kristoff's belief that having a science coach work with the teachers in their school would act as a fertilizer for further collaborations amongst teachers at later times about content learning to solidify their understanding, and apply continual learning. However, as wonderful as the above suggestions are:

Until they [Ministry of Education] decide that money is going to be distributed differently, good luck with that. Until somebody goes ‘we're stopping and starting all over from scratch’, until the day that happens nothing's going to happen. It's not that people aren't trying, but this is the money we have. It is the money being spent somewhere else or in a different way. Until we decide to change the model,

we can do all the work we want about this, but the current model doesn't reflect that kind of practice [teachers' engagement in ongoing CPL]. (Kristoff)

The following is an example of the potential benefits that could result from providing teachers with designated time within the Collective Agreement to collaborate. Co-planning and co-teaching did result from Anna, Elsa, and Belle participating in the first focus group. Anna (Grade 2/3) and Belle (Grade 7) realized they were conducting similar experiments with their students using catapults to teach forces. Not only did Anna and Belle discuss what they were teaching, they co-taught a lesson involving catapults. Anna expressed that the teachers did not have the time to collaborate and “had we not been at the meeting on the [day of first focus group] we never would have talked about the fact that we did the same thing. It is just the time to have the conversation”. Kristoff reported that it was an excellent success with 52 students in one class with Anna and Belle teaching and working with the students: “there was collaborative teaching going on (...) so it was excellent” (Kristoff).

Lastly, the value of providing time CPL for science education within the work day was important to Anna, Elsa, and Belle. They spoke about how they would appreciate having designated time for ongoing CPL within the school day because “it is so hard to connect with people before and after school. I have to run out at 3:30 some days to get to some place, or sometimes at the end of the day I'm done” (Belle). If Collective Agreement was modified to provide time for CPL within the work day, the teachers suggested preferable times. For instance, Belle said she would prefer to have “scheduled meetings (...) in the middle of the year so I can get everything laid out. But collaboration is something you need to do every time you plan a new unit really or every six weeks”. Anna said: “It's definitely ongoing. But at the beginning of the year, you can plan out what it should look like or what you want but then ongoing has to happen as well”.

Section 2

Teachers' beliefs (self-efficacy, pedagogical discontentment, epistemological beliefs) appeared to be positive influences on their openness to CPL related to science. Each teacher was receptive to engaging in CPL related to science on an ongoing basis to improve their science teaching, and in turn, student's science learning.

The results from Anna, Elsa, and Belle's surveys are presented in the following manner: (a) Professional Development Logs, (b) self-efficacy from the Science Teaching Efficacy Beliefs Inventory – A, (c) pedagogical discontentment from the Science Teachers' Pedagogical Discontentment scale, (d) beliefs about teaching and learning from the Beliefs About Reformed Science Teaching and Learning questionnaire. Notably, the survey results are presented in conjunction with the responses from the professional development logs, and narratives from the focus groups. Lastly, the teachers' beliefs about remaining a novice science teacher is discussed.

Teacher professional development log results. Table 7 provides a detailed record of each teacher's engagement in CPL related to science that occurred over a period of five months. Next, Table 8 shows the number of CPL entries per teacher, per month, and the minimum amount of time teachers spent on the CPL activities for the duration of each month. The time spent on CPL was recorded as the minimum number of hours as the option often selected was listed as engagement in a CPL activity to be more than 90 minutes. The exact time was not recorded (see Table 7). From a potential of 15 logs, a total of eight were received: Anna submitted a total of four logs, Elsa submitted three, and Belle submitted one.

Table 7

Teachers Recorded Engagement in CPL related to Science from December 2014 to April 2015

Variable	Anna	Elsa	Belle	Total
Activity				
Courses, conferences, seminars, workshops attended	2	4	1	7
Training/studying for credential(s)				
Distance-education courses/modules you completed				
Presentations you gave, articles/books published, posters presented, courses taught	1			1
Consulting with peers, informal rounds with colleagues, mentoring (mentor or mentee)	12	11	1	24
Reading journals/texts, publications; reviewing videos/DVDs for specific learning goals	2			2
Independent research or using other resources		4		4
Professional contributions (committee work, peer reviews)	2			2
Other	7			7
Purpose of Activity				
Discussion for assessment	2	2		2
Discussion for evaluation	2	4		6
Discussion for lesson planning	11	12	1	24
Other	12	1	1	14
Time spent on the Activity (minutes)				
10	1	2		3
15	4	4		8
20	3	1		4
30	4	5		9
40				
50	1			1
60	7	1		8
70				
80				
90	2			2
90+	5	6	2	13

(continued)

Variable	Anna	Elsa	Belle	Total
When the CPL happened				
Scheduled time	19	6	2	27
Prep time	2	3		5
Lunch break				
After school hours	3	4		7
Before school hours	1			1
Hallway chatting	2	6		7
Other				
Who teachers collaborated with				
Colleagues from the same grade	1	3	1	5
Colleagues from different grades	24	12	1	37
Other	2	4		6
Active Learning				
Observe lessons of teaching technique	5	2		7
Lead group discussions	1			1
Develop curricula or lesson plans, which other participants reviewed	2	2		4
Reviewed students work or score assessments	1	4		5
Develop assessments or tasks	4	8		12
Practice what you learned and received feedback			1	1
Received/provided coaching or mentoring in the classroom				
Gave a lecture or presentation to colleagues	1			1
Other	13	3	1	17
Coherence				
The activity is consistent with your department or grade level plan to improve teaching	4	15		19
The activity is consistent with your own goals for your professional development	23	4	2	29
Based explicitly on what you have learned in earlier professional development activities				
Learning Outcome				
I changed or modified/plan to modify my practice based on this learning activity.	2	10	1	13
I pursued/will pursue additional information.	4	2		6
The findings of this activity reaffirmed or enhanced my knowledge, and no change to my practice is needed at this time.	19	7	1	21
Other	2			2

Table 8

Number of Activities Recorded and Time spent on CPL for Science

	Anna		Elsa		Belle	
	<i># of CPL Activities Recorded</i>	<i>Time (h) spent on CPL</i>	<i># of CPL Activities Recorded</i>	<i>Time (h) spent on CPL</i>	<i># of CPL Activities Recorded</i>	<i>Time (h) spent on CPL</i>
December	8	4.7	2	2	2	2
January	0	0	0	0	0	0
February	8	6.9	0	0	0	0
March	5	3.6	9	4.5	0	0
April	6	5.3	9	6.7	0	0
Total	27	20.5	19	13.2	2	2

Anna, Elsa, and Belle expressed two reasons for the low response rate for completing the professional development logs. First, the teachers felt that the professional development logs “are just time consuming” (Elsa) and added to their workload. Because teachers had other priorities that took precedence such as numeracy and literacy, completing the log took time away from those more pressing tasks. Belle explained her view about completing additional paperwork such as the professional development logs in the following way:

It all comes back to teacher workload. By the time you are trying to contact parents and mark... Like, Lesson 7 and 8, we both have a massive stack of marking to get through. So it's more the workload. Once you hit the year, you don't have time to get a lot of extra stuff in. (Belle)

Secondly, Elsa and Belle rarely completed the logs because they did not believe that it was a valuable use of time as it was not helpful for their teaching practice: it took time away from planning, marking or other tasks. The idea of adding to their workload was heavily weighted as Anna, Elsa, and Belle indicated that their workload was the greatest

factor that reduced their time to collaboratively or individually plan lessons. For instance, Elsa did not believe that recording her CPL activities was “helping my teaching because if anything, it takes away time from prepping, learning or doing it. It is just one more thing that I don’t feel I learn anything from it” (Elsa). On the other hand, Anna enjoyed completing the logs because it was an opportunity for her to reflect on her CPL related to science and see how she could have improved her teaching practice. Anna expressed her opinion in the following way: “I look at the log and say, ‘we did talk about science’ or ‘we didn’t talk about science at all’. So I can sit back and reflect on what I have done.” In one of the focus groups, Anna commented about being able to reflect on her practice in the professional development logs and how it helped her to re-evaluate her teaching practice using inquiry-based pedagogy: “reflecting on science and how much time is spent on teaching it versus other curriculum areas is always beneficial. It provides the opportunity to re-evaluate whether enough hands-on opportunities are being provided”.

Lastly, the teachers openly expressed that the professional development logs were not an accurate representation of their CPL activities related to science. As previously mentioned, Elsa and Belle’s collaboration was not planned. They would collaborate with one another and then part ways and forget they collaborated because they had other tasks to attend to. So, “hallway” collaboration (in Table 7) was not an accurate representation of how often they actually collaborated. Belle and Elsa expressed their views in the following ways:

They are random conversations. Sometimes you don’t realize that you are doing it. Sometimes it’s passing in the hall or we are in the photocopy room and all of a sudden talking about sharing short stories. By the time you get back to your classroom, you forget that you had that conversation. (Belle)

I looked back through my daybook to get most of my dates, because school has been crazy. There was a lot more in the hallway collaboration that occurred, but I couldn’t name it exactly. (Elsa)

Measures of Anna, Elsa, and Belle’s affective state toward engaging in CPL related to science

The results from the surveys, Science Teaching Efficacy Beliefs Inventory – A, Science Teachers’ Pedagogical Discontentment, and Beliefs About Reformed Science Teaching and Learning are addressed below, along with a narrative from the focus groups with Anna, Elsa, and Belle, and results from their PD logs, and interviews with Kristoff.

Science Teaching Efficacy Beliefs Inventory – A. Elsa had the highest overall score of 60 on the Personal Science Teaching Efficacy questions. Then, Anna had the second highest score of 53. Lastly, Belle had the lowest score of 47. In this capacity, Elsa and Anna were considered to have high self-efficacy, while Belle had medium self-efficacy.

During the focus groups, each teacher spoke about their science background and how it affected their self-efficacy with regards to science. Notably, the results from Personal Science Teaching Efficacy scale were harmonious with their commentaries during the focus groups. In the focus group, it was clear that Elsa felt the most confident in her ability to successfully teach science as she would say statements such as: I am “comfortable [teaching science] because science is my background. I know what students are seeing so I understand why it is happening. We can talk about it or I can explain”. Following, Anna was slightly less confident in her ability to successfully teach science. However, she was confident knowing that she had a strong understanding of how to teach using the DRiVe model and she was still confident for the reason that she was teaching Grade 2/3, which did not require her to have a strong background in science:

I’m lucky because teaching grade 2/3, I don’t have to have the deeper understanding. I understand science enough that I’m now comfortable with it. I wasn’t before doing DRiVe. I wasn’t comfortable with it at all. It was because, for me, science is not my background so there should be an answer. But now I’m completely understanding. (Anna)

Lastly, Belle was the least confident in her ability to teach science and it was evident during the focus groups because she would verbalize it. For instance, Belle remarked: “I’m not as comfortable precisely for that science is not my background. I have only taught it at this age for about two years”. As a result, teaching science made Belle feel

“more uncomfortable than if I were teaching history or language that I feel like I’m more of advanced”. Belle felt uncomfortable teaching science because of the array of variables that could influence an investigation. For instance, Belle said:

One thing I find with sciences is that there are so many things that could affect the variable. If something goes wrong, did it happen because of this or that? I find that aspect a little hard – that I have to have such a broad knowledge base or to be able to say to them, I’m not sure maybe it’s this, so let’s try and find the answer. (Belle)

In addition, Anna, Elsa, and Belle’s self-efficacy appeared to influence their teaching style. It seemed as though the higher their self-efficacy to teach a science unit, more hands-on activities were conducted with their students. Note that the relationship between self-efficacy and instructional strategies that were implemented in the classroom was with regards to self-efficacy related to specific units/topics, not self-efficacy as a whole for teaching science. For instance, Belle expressed her view in the following way: Belle said that her inquiry-based teaching “depends on the unit and where I’m at”. Also, Anna said:

If I am comfortable with a topic, there are more things I can see pulling into teaching it. So that’s why they would do more hands on. I could see how we could do this to show this part or things like that. But If I’m not comfortable with the topic, it would be whatever I read about and that’s it. (Anna)

Science Teachers’ Pedagogical Discontentment scale. Each teacher was pedagogically content with their science teaching as they each had total scores below the mid-point of 63. The overall scores were 54 for Belle, 38 for Elsa, and 32 for Anna. Also shown in Table 9, based on the 5-point scale per subcategory, Belle was the most discontent with her science teaching out of the three teachers.

Table 9

Descriptive Statistics (modes) for Teachers' STPD Scores

	Anna	Elsa	Belle
Ability to teach all students science	1.00	2.00	2.00
Science content knowledge	1.00	1.00	2.00 & 3.00
Balancing depth versus breadth of instruction	3.00	1.00	2.00
Implementing inquiry instruction	1.00 & 2.00	2.00	4.00
Assessing science learning	1.00	2.00	3.00
Teaching nature of science	2.00	No mode	No mode

Anna, Elsa, and Belle's receptivity to engaging in CPL related to science. The hypothetical vignette by Southerland et al. (2011a) looked at the receptivity of teacher engagement toward CPL related to science based on their overall pedagogical discontentment (from the STPD) and their overall personal science teaching self-efficacy scores (from the STEBI-A). Using the vignette as a point of reference and the results from the surveys, Anna, Elsa and Belle were not receptive to changing their teaching practice from engaging in CPL activities because they were generally content with their current teaching practice *and* believed that they were capable of executing their teaching practice for students to be able to achieve an understanding of the scientific principle being taught (they had high levels of self-efficacy related to science teaching). On the contrary, based on the discussions with Anna, Elsa, and Belle during the focus groups and their results from the professional development logs, Anna, Elsa, and Belle were content with their science teaching but still wanted to improve. The teachers expressed that they were keen to participate in any CPL activities related to science because they felt that their participation helped to improve their science teaching, and in turn, they perceived that their engagement in CPL related to science helped to improve their students' science learning. Below, specific reasons are provided.

First, as mentioned in Theme 1, Anna participated in the Science Task Force once a month for an entire day, and Elsa and Belle participated in Sector Projects. Based on

data collected from the surveys, focus groups, and professional development logs, it would not be accurate to say that any one of the teachers was more or less receptive to CPL activities; they appeared to be equally engaged and eager to participate. In addition, Kristoff raved about how Anna, Elsa, and Belle were eager to participate in CPL activities to further their science learning: “I’m way past enthusiastic, way past, beyond pleased. We have great people who are excited about learning and teaching science to our students”. Below are examples of how Anna and Belle their opinions about their receptivity to participating in CPL related to science:

As long as there are people to collaborate with. I mean, I would never have a problem. (Anna)

I was thinking the same thing. You are talking to three people who are willing to take risks and are willing to collaborate. If there are any science workshops that I can do, I try to get into them because I’m not as comfortable as you [Elsa] to begin with. Anything I can find that will help or make it more interesting, I will jump on. (Belle)

The second reason behind the Anna, Elsa, and Belle’s openness to participating in CPL activities related to science was that it stimulated them to modify their science lessons to be more inquiry-driven. For instance, Anna made the following remarks on her professional development logs about CPL activities that helped modify her teaching: “I changed previous lessons from teacher led, basic experiments to inquiry-based lesson”, and that engagement in CPL related to science “allowed me to understand how to change experiments to allow for students to drive their own learning”. Also from the professional development logs, Elsa expressed how her participation in CPL helped to modify her teaching practice for science: “I have adapted some of my teaching focus to basic skills rather than knowledge-based” and “I added another inquiry experiment to my lessons”. Interestingly, during the focus groups, Anna, Elsa, and Belle emphasized that the CPL activities that they perceived to have helped improve their teaching and student’s science learning stemmed from the Sector Projects and the Science Task Force. The reason for those particular activities being perceived as extremely helpful was that they were coached by expert science coaches from whom they gained “ideas for hands-on things and how I can better teach my kids the concepts they need to grasp” (Elsa). Part of the benefits of being coached was that the teachers became aware of tactics to help improve

their science teaching based on their needs. For example, Anna also expressed that from various CPL activities, she would further her learning by reading “the book about assessment and evaluation over the summer and determine what strategies I can incorporate in the next school year.” Although Anna, Elsa, Belle, and Kristoff raved about learning science with the assistance of a science coach, during the five months that teachers recorded their PD activity on the logs, no one said they were provided coaching or mentoring in their classroom within the school environment.

Lastly, Anna, Elsa, and Belle perceived their science learning and in turn, their ability to then modify lessons based on their new or refined learning from engaging in CPL helped to improve their students’ science learning. For instance, Elsa said: “collaboration is always going to lead to teachers learning and student learning will come out of that - sometimes or eventually”. Notably, Anna, Elsa, and Belle considered student learning to be based on the learning curve that individual a student achieved, not whether a student improved his/her grade on a report card. For instance, Anna said:

I think if you're measuring achievement based on where they are, to where they end up being, you can see their learning. I think if you measure achievement based on the expectation of a curriculum, maybe not everyone is achieving. But if you look at where the students are and what they've done, I would say yes to student achievement. (Anna)

Belle provided two examples of how she perceived her learning helped to then improve her students’ learning. First, Belle participated in a Putt Putt Boat investigation that was part of a Sector Project. After engaging in the activity, Belle believed that she was not confident in her skills to teach the activity, but “by having that collaboration and seeing it, I brought back an understanding of variables that I could then pass on to the students” (Belle). The second example was that beside improving her repertoire and applying her learning immediately, or in the future, Belle spoke about how she attended a Sector Project to learn “about troubleshooting concepts because there was a lot of trouble shooting happening – look for that variable or that variable”. Belle’s new understanding of what happened when variables changed in an investigation was helpful to her students because she felt more comfortable and confident in her ability to facilitate the investigation with her students. Thus, she felt as though she was able to provide “richer learning experiences for students” (Belle).

Beliefs About Reformed Science Teaching and Learning. Anna, Elsa, and Belle scored over the mid-point of 80, leaning toward the reformed perspective (scores above 80) compared to the traditional perspective (scores below 80). Anna's total scores was 97, followed by Elsa with a total of 88, and Belle with a total of 85. The mode based on a 4-point scale for each subscale is provided in Table 10.

In comparison to the discussion amongst the teachers during the focus groups, the results were an accurate representation of their beliefs about learning and teaching science. Anna, Elsa, and Belle expressed that they taught with an approach that was more so leaning toward a balance between lecture and constructivist teachings. The main reason for teachers relying on both strategies was that a large proportion of students had not had previous experience learning science using inquiry-based pedagogy. So, teachers felt that students needed a combination of hands-on and theory work to learn about the science topic being taught. Each teacher expressed her view in the following ways:

I do a bit of both. We almost always do some sort of student-centered activity, but I may follow up, or precede with, some theory behind what they found with notes. For example, we will write a note and then do an experiment to see if it worked out - or vice versa. I would say my kids this time have struggled with putting ideas together. If I just do student centered, they have struggled to get some of the connections. (Belle)

A lot of our student-centered work is done at first because you let the kids experiment and then you teach them the theory behind. A lot of the kid's need the solidification of learning like [Belle] said – to actually get the theory behind it. (Elsa)

I would say it is both as well. I'm leaning a little bit more to student-centered, but I'm involved in the consolidation because they do something but yet still they will not put it together with the idea and the concept that they are learning so I will have to draw a connection for them. (Anna)

Thus, regardless of Anna, Elsa, and Belle holding reformed values about teaching science, and believe in teaching science using the DRiVe model, they felt they were unable to fully educate their students using the DRiVe model because the students were not prepared for that type of learning – they were familiar with textbook learning.

Table 10

Descriptive Statistics (modes) for Teachers BARSTL Scores

	Anna	Elsa	Belle
How people learn about science	4.00	2.00	3.00
Lesson design and implementation	3.00	3.00	3.00
Characteristics of teachers and their learning environment	3.00	3.00	3.00
The nature of the science curriculum	3.00	3.00	3.00

In fact, Anna, Elsa, and Belle's application of both teacher and student-centered instructional strategies was approaching Kristoff's goal for teachers to move away from teacher-centered, lecture style pedagogy toward "what's called an 80/20 model. In other words, 20% of the time is teacher directed that may be both at the beginning or end of the class, and 80% of the time is kids hands-on facilitation" (Kristoff). Also, Kristoff wanted both teachers and students be comfortable with the idea of "failing". Meaning, he wanted teachers to teach students by having them "try an experiment and be creative and innovative and not be worried about what mark or grade they are going to get"; the process of engaging in, and learning from, inquiry-based activities was of utmost importance. However, for teachers to be able to embrace this concept, they would have had to "worry less about giving kid's information, and more so teaching them how to find it, and ask questions about it, and think outside that information to apply and communicate it". Kristoff believed that constructivist-based teaching was "more important than just knowing some information because that doesn't mean anything in the world to live in today". Although Anna, Elsa, and Belle were applying both teacher and student-centered approaches, they did not feel that they were achieving the 80/20 split as desired by Kristoff. Elsa and Belle explained the reason being was that their students were taught by previous teachers who only taught with traditional lecture styles. So, Belle and Elsa stressed that their Grade 7 and 8 students had not previously learned science using hands-on activities and were unsure of how to learn through experimentation:

Some of the kids are coming from teachers who are a lot more comfortable with, here's the text book, do this page and go that way. They've done a lot of book learning, so they haven't had inquiry lessons. Even though it [the DRiVe model] is out there, not all teachers use it. (Belle)

Half of my Grade 8's are okay because Belle had them for science last year. But the other kids had never done hands-on or inquiry work. Those kids are needing the teacher directed learning in the consolidation because they are floundering; they have never done it where there has been an experiment and then learn from that. This year I have some of Belle's Grade 7's from last year who are comfortable with inquiry. Then the other kids who haven't done inquiry before are still struggling with it. (Elsa)

As a result of some students not having past experiences learning science by using the DRiVe model, Elsa and Belle, in particular, felt that those students had a long learning curve to “get the understanding that they can't fail. A lot of kids think that they can fail, but they can't fail – it's inquiry and it's *you* doing it. So the kids are very cautious about it (Elsa). In this capacity, Elsa and Belle felt as though they need to engage in more “teacher directed lessons because we are trying to teach them inquiry, not just science. Because the inquiry model is student-centered, we have to teach them that model, which is teacher directed” (Elsa). Thus, Anna, Elsa and Belle's application of traditional and reform based pedagogy was influenced not only by their personal beliefs, but the instructional strategies that past teachers applied with their students and possibly their beliefs about the nature of science learning and teaching. Lastly, referring back to Theme 1, the lack of consistent teaching styles using the DRiVe model inhibited Anna, Elsa, and Belle from collaborating within and across academic teams.

Beliefs about remaining a novice science teacher. Each teacher perceived science to be dynamic in nature – ever evolving and not static – and should be taught using student-centered, inquiry-based pedagogy. Their beliefs about science may have influenced their opinion that they will forever remain novice science teachers because they will never truly “master” science. This is regardless of whether Anna, Elsa, or Belle was considered a beginner or experienced teacher according to the Ontario Ministry of Education or the total number of years she had been teaching, and her active engagement in CPL activities related to science. Anna and Elsa described their reasoning in this way:

I don't think I'd ever perfectly feel comfortable [teaching science] because the whole inquiry thing is that there they're doing things and changing variables that they're interested in. So I don't think that I'd never really predict what students are going to want to change or predict the questions that they're going to ask me. So I

think that every year, depending on kids, is always going to be different because are all coming in different knowledge. (Anna)

It is very student dependent so I don't know if I would ever feel very comfortable. I think you only become an expert if you keep doing the same things but like, science is always adopting and changing and you're always doing different things. It is never the same thing over and over and over again. So it's not like math where a triangle is a triangle. Because I base a lot of stuff on current events, I don't think there will ever be that expert level because it is not repetitious. (Elsa)

Chapter Summary

Chapter Five presented the findings that were uncovered in this study, and Figure 3 depicts a brief summary of the main topics that emerged to address the multiplicity of factors that affected Anna, Elsa, and Belle's engagement in CPL related to science education. The chapter was organized to present the school principals' and teachers' findings by discussing two sections: first being the results from the qualitative data, and the second being the results from the quantitative data which is then supported by the qualitative data. The two sections also addressed each research question. Data from professional development logs, surveys, focus groups with the Anna, Elsa, and Belle, and interviews with the Kristoff revealed their perceptions about the multiplicity of factors affecting Anna, Elsa, and Belle's participation in science CPL. Each finding was supported by quotations to convey the participant's viewpoint to the reader, and to accurately represent the reality of the participants. The results presented in this chapter indicate that teacher engagement in CPL related to science is not straightforward and is intertwined amongst a multitude of factors related to teachers, administrators, and ministry level regulations. This should give pause to making blanket assumptions about teacher engagement in professional learning related to science. Factors beyond teachers and Kristoff are limiting their engagement, although teachers may be eager to engage in professional learning related to science and Kristoff may be willing to facilitate their learning. In the next chapter, the analysis, interpretations and synthesis of findings will be discussed and placed within a context of current and future research and their implications.

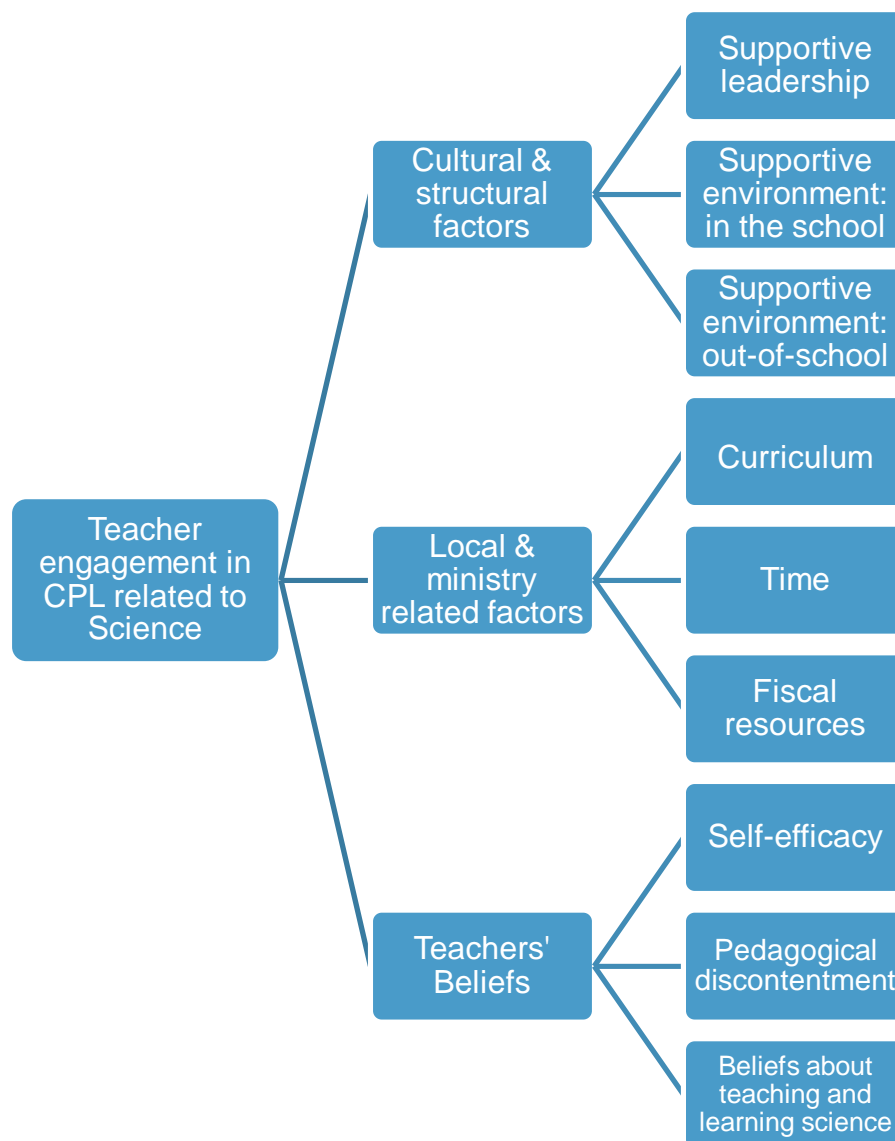


Figure 3. Summary of topics that emerged from the research findings.

CHAPTER VI: DISCUSSION

The descriptive nature of this case study provided an avenue for a literal reporting of the multiple variables of importance from a socially constructed, complex, real-life situation about the multiplicity of factors affecting elementary teacher participation in collaborative professional learning (CPL) related to elementary science education. Based on the literal reporting of the research findings discussed in the previous chapter, adopting the methodological approach allowed for an intensive, authentic investigation into the five research questions in the current chapter. Thus, the research strategy chosen for this study helped to achieve the research purpose, which was to unveil multiple and competing standpoints between the views of teachers and their principal about the ability to participate in CPL and its relationship to teaching science. Moreover, the descriptive case study helped to recognize and appreciate the holistic view of the tensions which characterize teacher engagement in CPL related to science and potentially help to align teacher efforts and system goals.

This research study is viewed through the lens of Situated Learning Theory. From this perspective, teacher engagement in CPL related to science education is a social phenomenon in which collaborative practices and the construction of meaning was rooted in the experienced, lived-in world with ongoing social practice (Lave, 1991; Wenger, 1998). In terms of methodology, the study investigated the contextual and personal experiences and interactions that teachers experienced over six months of the 2014-2015 school year with regards to their engagement in CPL about teaching science. This research applied a qualitative inquiry approach by conducting in-depth interviews and focus groups, surveys and professional development logs. Participants included three elementary teachers - Anna, Elsa, and Belle - who taught science to Grades 2/3, 8, and 7, and their school principal, Kristoff. In Chapter V, the data was coded, analyzed, and organized by themes that were most prevalent to address the research questions in this current chapter. The rationale for placing Anna, Elsa, Belle, and Kristoff at the centre of this research study was to demonstrate that research with teachers is the most productive approach to teacher learning and change (Loughran, 2014). Teachers have understandings that have been developed within the school context on a daily basis, which goes “far beyond what the expert researchers have produced” (Kincheloe, 2003, p. 18).

To compose the current chapter, I first identified connecting patterns that emerged from the findings presented in Chapter V. Following that process was a secondary analysis that included addressing relevant theory and research that tied into the patterns that emerged in the primary analysis. Addressing the research body and theory helped compare and contrast issues that have been raised in the literature. The discussion is based on three overarching concepts that are interpretive insights and implications into the synthesis of the findings. The three predominant areas for discussion are:

1. The lack of emphasis on science in Ontario's elementary education
2. The limited time available for CPL about science
3. The limited number of teaching partners to collaborate about science

Teacher knowledge and perceptions, administrative support, professional learning, and available resources, among other factors, are intertwined with student experiences with inquiry, teacher collaborations, technology use, and other aspects of the education system. Thus, the three predominant areas for discussion are intertwined through the research questions because “limiting findings to isolated categories is inevitably an oversimplification” (Lewis et al., 2015, p. 900). While discussing the five research questions, I show the interconnectedness of the three concepts and help readers to recognize that the concepts represent multiple and complex overarching domains that greatly influence teacher engagement in CPL related to elementary science education in Ontario, Canada. Unlike the previous chapter that presented objective data gathered from Anna, Elsa, Belle, and Kristoff, the purpose of this chapter is to provide interpretive insights and implications into the synthesis of the findings, being the predominant areas for discussion, and to construct a holistic understanding of the phenomenon.

Research Question One: What are the perceptions of teachers and their school principal regarding CPL related to science as a vehicle for their professional growth related to science?

Anna, Elsa, and Belle, perceived their active engagement in CPL related to science to be an effective vehicle to improve their science teaching because of reasons related to: (a) meeting their classroom needs, and (b) time. After discussing the two reasons, two underlining affective constructs - self-efficacy and pedagogical

discontentment - are discussed in terms of why they may have been influential to Anna, Elsa, and Belle's professional growth based on their engagement in CPL related to science.

Recall that Kristoff employed a bottom-up leadership style and placed equal value on school subjects including science. Although science was not included in the School Improvement Plan, Kristoff was supportive of Anna, Elsa, and Belle's voluntary engagement in CPL related to science because he was aware that their engagement helped to improve their inquiry-based science teaching. From Anna, Elsa, and Belle's perspective, their active engagement in CPL related to science was perceived to be an effective vehicle for improving their science teaching because they voluntarily chose activities that were specific to their classroom teaching needs; there was a strong degree of coherence between their science teaching goals and their engagement in CPL related to science. As Penuel et al. (2007) explained, professional learning needs to be in response to teachers' teaching needs to be effective. For instance, Anna, Elsa, and Belle's in-school, unplanned, hallway discussions that were collaborative in nature were directly related to their teaching needs, including talking about specific students learning needs, how to use specific equipment, and/or plan for investigations or lessons. With regards to the out-of-school CPL activities, Anna, Elsa, and Belle's learning was also perceived to be related to their classroom needs. During this time, they were guided by science coaches who taught Anna, Elsa, and Belle exactly how to conduct inquiry-based investigations that were tailored to their curriculum level and that could be replicated in their classroom considering the time restrictions and limited fiscal resources available to purchase new materials. If Anna, Elsa, and Belle had not participated in the out-of-school activities, they would have never been taught how to teach specific investigations that were applicable in their classroom – they would have had to learn on their own. Thus, similarly to other researchers (e.g., Butler & Schellert, 2012), the benefit of engaging in the CPL activity that involved inquiry-based learning was the potential for teachers to alter their teaching practice or undergo educational change.

In relation to time, Anna, Elsa, and Belle perceived the out-of-school CPL related to science improved their science teaching and learning because their engagement provided extended periods of time to focus on learning about how to conduct science

investigations that were relevant to their classroom needs with the help of the science coaches. Notably, the amount of time it took for Anna, Elsa, and Belle to implement changes to their teaching practice based on their engagement in CPL related to science with a science coach was unknown from this descriptive case study. Research has shown that longer durations of professional learning activities have been the most effective in making changes to teacher practice (e.g., Banilower et al., 2007; Cotabish et al., 2011; Gerard et al., 2011; Lewis et al., 2015; Smith, 2015; Yoon et al. 2007). Supovitz and Turner (2000) analyzed cross-sectional data from 24 Local Systemic Change initiative that involved the K-8 science component from the National Science Foundation Teacher Enhancement program. The Local Systemic Change initiative was meant to support teacher's improvement to their science teaching. They found that to increase inquiry-based science practices, at least 80 hours of high-quality professional learning were needed for teachers to establish an investigative classroom culture. Notably, the 24 initiatives involved in the research had science teachers participate in a wide range of high-quality professional learning whereby some teachers were provided training, some relied on volunteers and provided incentives. Some teachers participated more intensely than others such that some teachers in the initiatives did not receive any professional learning. In comparison to what Anna, Elsa, and Belle wrote in their professional development logs and voiced during discussions, it is reasonable to say that none of the teachers took at least 80 hours of professional learning to start implementing changes to their teaching practice by using the DRiVe model. Recall that Anna, Elsa, and Belle independently completed the professional development logs for five months (excluding the pilot month) during the 2014-2015 school year. The professional development logs provided an avenue to understanding Anna, Elsa, and Belle's engagement in CPL related to science and how their engagement was part of the "social practice in the lived-in world" (Lave & Wenger, 1991, p. 35) of elementary education. Anna recorded that she engaged in CPL for a total of 20.5 hours, Elsa recorded a total of 13.2 hours, and Belle recorded a total of 2 hours. Although the logs were not accurate representations of their engagement as each teacher admitted to not always remembering their participation or not having the time to complete the logs, it may be unreasonable to say that each teacher spent at least 80 hours on their CPL related to science considering that they continuously

spoke about how they did not have time to focus on science because numeracy and literacy took precedence. The point is that even with 20.5 hours or 2 hours of recorded engagement in CPL related to science, Anna, Elsa, and Belle spoke about how their active engagement influenced their teaching practice considering that they implemented their learning about DRiVe investigations in their classroom practice. This research does not support Supovitz and Turner's findings in the sense that at least 80 hours of professional learning was necessary before making changes to their teaching practice. However, it may be reasonable to conclude that science coaching and the offshoot discussions specific to their needs is what makes CPL effective because it is specific to teachers' teaching needs. Thus, teachers then implement their learning to their classroom practice nearly immediately.

Moving forward from the two reasons as to why Anna, Elsa, and Belle's engagement in CPL was perceived to have helped improve their science teaching, the two affective constructs - self-efficacy and pedagogical discontentment - related to science education are discussed to better understand the reasoning behind why Anna, Elsa, and Belle voluntarily wanted to pursue learning about science. Researchers (e.g., Sowell et al., 2006; Southerland et al., 2007; Saka et al., 2009c) have suggested that a teacher with a combination of pedagogical discontentment and high self-efficacy may be more receptive to reform initiatives within professional learning activities and make changes to their teaching practice. In terms of pedagogical discontentment, it appeared that Anna, Elsa, and Belle engaged in CPL related to science to improve their inquiry-based science teaching because teaching science was a weakness or a gap in their teaching. Being aware of their weakness was perceived to have helped motivate each teacher to voluntarily engage in CPL related to science and to apply their learning to their teaching practice. Recall that Anna, Elsa, and Belle were also teachers who were willing to take risks, to collaborate and were generally "keen science learners" (Kristoff). Thus, the results of this study were similar to Blanchard and Grable (2009), and Golden et al. (2010) who found that teachers (including those who taught science) who were pedagogically discontent applied reform-based teaching strategies in their teaching practice after engaging in professional learning activities. The research findings were also similar to Adigozel, Saka, and Colakoglu (2012) who focused on 104 elementary science teachers in Turkey.

They found that having moderate levels of pedagogical discontentment was a key prerequisite to implementing inquiry-based investigation in their classroom teaching. Due to the descriptive nature of this research study, it was unknown whether: (a) the dissatisfaction that Anna, Elsa, and Belle felt with their science teaching was a cause to their engagement in CPL related to science, (b) the teachers were generally interested in learning more about the DRiVe model for other intrinsic or extrinsic motivation factors, or (c) their engagement was due to a combination of having a supportive principal, a school culture of professional learning and the motivation to further their professional learning in science. Regardless, it appeared that the research findings may support Southerland et al. (2012) and other researchers (e.g., Feldman, 2000; Southerland et al., 2011a; Sunal et al., 2001; Woodbury & Gess-Newsome, 2002) who have claimed that teachers teaching science need to be dissatisfied with their current ideas of teaching science to be motivated to transform their practice; the feeling of dissatisfaction with their teaching practice gave teachers the motivation to engage in new, beneficial and enlightening reform teaching.

There were inconsistent results between what Anna, Elsa, and Belle expressed in the discussions compared to what they reported on the Science Teachers' Pedagogical Discontentment survey. According to the survey, Anna, Elsa, and Belle were considered to be pedagogically content with their science teaching practice. Meanwhile, based on the multiple hours of discussions with the teachers, it appeared that regardless of how good their science teaching was, there would always be room for improvement. Anna, Elsa, and Belle were go-getters and wanted to improve their teaching practice; they were "keen" learners as Kristoff highlighted. Thus, regardless of whether Anna, Elsa, and Belle were content with their science teaching, they believed that their teaching could be improved and that the out-of-school CPL activities related to science were productive means to improving their science teaching and the learning of their students regarding science. Although Anna, Elsa, and Belle may have said they were pedagogically content on the survey, upon engaging in in-depth discussions, they verbally made it clear that science was a weakness, they were not content with their science teaching, and that they wanted to improve their teaching as they were motivated to do so.

Next, Anna, Elsa, and Belle's self-efficacy related to science education is discussed. Recall that according to the Science Teaching Efficacy Beliefs Inventory-A, Elsa had "high" self-efficacy, followed by Anna, and then Belle with "medium" self-efficacy. When Anna, Elsa, and Belle provided reasons for their self-efficacy regarding science teaching, they spoke about their formal education and the length of time of their personal teaching experiences, which are two of the six sources that develop beliefs, including self-efficacy, outlined by Buehl and Fives (2015). For instance, Elsa had the highest perceived self-efficacy because her undergraduate studies related to science. Belle had the lowest self-efficacy because she was new to teaching science to intermediate levels and she did not have a formal educational background in science. Note that Anna, Elsa, and Belle's survey results and discussions about their science self-efficacy were congruent.

Anna, Elsa, and Belle's medium to high self-efficacy may have been an influential reason as to why they voluntarily engaged in CPL related to science. Or, it may have been that their engagement in the CPL helped increase their self-efficacy as they became more confident to teach inquiry-based investigations, manipulate variables, and use the necessary resources for specific investigations. Although it was unknown from this descriptive study whether Anna, Elsa, and Belle's self-efficacy related to science was a precursor to their voluntary engagement in CPL related to science, or whether their engagement was a precursor to their medium to high self-efficacy. Research has shown that teachers who engage in collaborative practices have increased teaching self-efficacy (e.g., Day et al., 2006; Flores & Day, 2006) and teachers who are more self-efficacious "are more likely to employ and seek out engaging instructional strategies" (Chen et al., 2015, p. 372). As Anna, Elsa, and Belle voluntarily sought out CPL opportunities related to science, they spoke about becoming more confident to: (a) relate science activities to real-world examples such as the trebuchet experiments, as found by other researchers (e.g., Haney et al., 2002; Riggs et al., 1998); and (b) engage in and incorporate more hands-on activities with their classroom students as reported by other researchers (e.g., Haney et al., 2002; Lakshmanan, et al., 2011; Marshall et al., 2009; Nolan et al., 2011). Overall, based on the feedback provided from Anna, Elsa, and Belle, each teacher had: (a) positive perceptions about the out-of-school CPL activities,

especially those that included science coaches, and (b) perceived that their self-efficacy increased from their participation. Like Cantrell and Hughes (2008) stated, it is possible that the combination of the two resulted in greater application of new knowledge gained from the professional learning activities to the classroom. Notably, studies have not proved that teacher's science self-efficacy is the variable that mediates the relationship between engaging professional learning activities and teacher behaviour. More research is necessary to determine the *causal* links between teachers' science self-efficacy, inquiry-based teaching and professional development (Chen et al., 2015).

After addressing Anna, Elsa, and Belle's pedagogical discontentment and self-efficacy independently, it was important to relate them to one another as Southerland and colleagues (2011a) did with their hypothetical model (see Chapter II). Recall that the authors looked at the relationship between pedagogical discontentment (using the Science Teachers' Pedagogical Discontentment scale) and self-efficacy, and then addressed teachers "resistance or openness to change" (Southerland et al., 2011a, p. 301) based on engagement in professional learning. Considering the results from the Science Teachers' Pedagogical Discontentment scale and self-efficacy score, Anna, Elsa, and Belle were pedagogically content and had medium to high self-efficacy. In comparison to the model, Anna, Elsa, and Belle would not have made changes to their teaching practice after engaging in CPL related to science because they were content with their current teaching practice *and* believed that they were capable of executing their teaching practice for students to be able to achieve an understanding of the scientific principle being taught. On the other hand, as mentioned previously, although the results from the Science Teachers' Pedagogical Discontentment scale expressed that Anna, Elsa, and Belle were pedagogically content with regards to their science teaching, upon engaging in multiple discussions, they made it verbally clear that science was a weakness - they were not content with their science teaching. In comparison to Southerland and colleagues model, Anna, Elsa, and Belle were likely to make changes to their teaching practice from engaging in CPL related to science. They were discontent with their current teaching practice *and* believed that they were capable of executing their teaching practice for students to be able to achieve an understanding of the scientific principle being taught. The combination of being pedagogically discontent and having medium to high self-

efficacy meant that they were open and receptive to changing and revising their teaching practice (Smith, 2005; Feldman, 2000). It is reasonable to say that Southerland and colleagues (2011a) model was an accurate representation of the results from this research study considering that Anna, Elsa, and Belle spoke at length during the discussions about how they implemented reform-based changes to their teaching practice as a result of their active engagement in the CPL related to science. Moreover, they believed that their improved instructional repertoire for science may have helped to improve the learning needs of their students related to science.

Research Question Two: How do teachers perceive that participating in CPL transforms their students' science learning?

In addition to Anna, Elsa, and Belle perceiving that their active engagement in the CPL related to science was an effective vehicle for improving their science teaching, they believed that their improved science teaching helped to improve their students' science learning. When addressing the learning of their students regarding science, Anna clarified that student improvement was gauged by measuring “achievement based on where they are to where they end up being. If you measure achievement based on the expectation of the curriculum, maybe not everyone is achieving there”. Similarly to other researchers (e.g., Lee et al., 2008; Yoon et al., 2007) who reported that science teacher engagement in CPL related to science showed an increase in student achievement, Anna, Elsa, and Belle spoke about and three reasons as to why their engagement in out-of-school CPL related to science helped to improve their students' science learning. Anna, Elsa, and Belle learned how to: (a) alter variables and use specific equipment according to an investigation with the help from the science coaches; (b) better tailor their classroom investigations to the learning needs of their students; and (c) better facilitate hands-on science investigations that were grounded in authentic, real-world contexts.

Anna, Elsa, and Belle believed their engagement in the out-of-school Science Task Force or Sector projects helped to increase student learning in science because the science coaches taught them how to manipulate variables and use equipment required for specific investigations – in turn, improving the science learning of their students. For example, Anna attended the Science Task Force whereby she learned about teaching forces using catapults, which variables could have been manipulated and their potential

outcomes. Anna applied her learning to her classroom practice and expressed that she was better able to guide her students through the investigation by manipulating different variables. The results were described as the students developing a deeper understanding of forces, asking questions that showed their critical thinking about the experiment and students were able to reason and rationalize their outcomes. Essentially Anna expressed a clear link between her learning and the learning of her students.

Next, Anna, Elsa, and Belle were better able to tailor their classroom investigations to the learning needs of their students. With the assistance of a science coach, they conducted an investigation for themselves and they saw how other teachers modified different variables. Meeting the learning needs of all students was a struggle for Anna, Elsa, and Belle because their students had varying degrees of understanding of the DRiVe model and how to conduct hands-on investigations. Some students had minimal experience because their previous teachers taught science with teacher-centered, traditional approaches, while other students were more advanced with their understanding as they had learned about and used the DRiVe model in previous years. So, the teachers struggled with facilitating a science inquiry project to a classroom of students who had varying understandings of how to engage in inquiry-based investigations – particularly when Anna, Elsa, and Belle were not confident about doing the investigation themselves. After Anna, Elsa, and Belle engaged in CPL related to science, they learned about an investigation and the potential variables to alter, and they felt more confident to teach students with various levels of understanding of the DRiVe model. Occasionally Elsa and Belle did not facilitate the full investigation that they learned in a Sector Project, but it still helped all students learn science and understanding about the topic at hand. For instance, Elsa engaged in a Sector Project about trebuchets. Rather than conducting the full experiment with her students, she conducted a couple of activities based on her learning from the trebuchet project to help all students understand the DRiVe model, as well as learn about the concept at hand. Elsa expressed that her collaboration during the Sector Project with a science coach and fellow teachers always lead to an improvement in student learning, regardless of whether she facilitated a full or partial investigation with her students based on their newfound learning. She applied her learning to their classroom practice and was better able to meet the needs of her students with and without

experience using the DRiVe model. Elsa and Anna expressed similar sentiments with their engagement in Sector Projects and the Science Task Force.

By participating in the Sector Projects and the Science Task Force, Anna, Elsa, and Belle believed that they also learned how to better facilitate hands-on science investigations that were grounded in authentic, real-world contexts. Anna and Belle provided an example whereby their participation in the Science Task Force and a Sector Project taught them about teaching forces by having the students use and build catapults and understand when catapults could be used and why. As outlined in the School Effectiveness Framework, Section 4.4, the teachers deepened students' science learning by engaging them in "exploring real-world situations/issues and solving authentic problems" so that they were not only learning discrete scientific facts – they were developing larger conceptual understandings of scientific principles. Moreover, Anna, Elsa, and Belle were meeting one of the goals of the Ontario 2007 revised science and technology curriculum, which was to relate science to the society and the environment.

Research Question Three: What does teacher participation in the practice of CPL related to science look like?

Anna, Elsa and Belle's participation in CPL related to science primarily occurred while they voluntarily engaged in the out-of-school CPL activities related to science (Science Task Force or Sector Projects) with the guidance of a science coach helping them progress through their classroom needs. The overarching reason for why Anna, Elsa and Belle's participation in CPL related to science primarily occurred while they engaged in the out-of-school activities was due to the predominance of numeracy and literacy in the Ontario elementary education system. Furthermore, due to the predominance of literacy and numeracy, there was a lack of opportunity for teachers to engage in ongoing CPL for science education within the school environment. To emphasize that most of the participation in CPL occurred out-of-school, the professional development logs showed that there were a prevalent number of recordings which included "consulting with peers, informal rounds with colleagues, mentoring" for the purpose of "discussion for lesson planning" that occurred for more than 1.5 hours at a time during "scheduled time" with "colleagues from different grades". Moreover, the professional development logs showed that the activities were consistent with the goals Anna, Elsa and Belle had for their

professional learning. To compare with Anna's verbal description of her engagement in the Science Task Force, she spent one day each month with a science coach learning about lessons that could be implemented in her classroom amongst other likeminded teachers in the primary division from various school in the district. Anna engaged in such activities because they were consistent with her personal goal of developing her instructional repertoire for science and for improving her students' science learning.

A combination of the findings from the professional development logs and discussions with the participants spoke volumes about CPL related to science being *one* aspect of Anna, Elsa, and Belle's teaching practice amongst a slew of other factors primarily related to numeracy and literacy. It appeared that their CPL related to science was limited to the Sector Projects or Science Task Force, the Grade 4-10 Transitions and Pathways Collaborative Inquiry project and brief hallways discussions. Moreover, in terms of the Sector Projects, they occurred beyond the school day as Elsa and Belle had to be online at seven o'clock in the morning to participate. The reasons for why CPL related to science was one aspect of Anna, Elsa, and Belle's teaching practice was that the teachers and their school principal believed there was (a) minimal accountability measures for elementary science education from the Ontario education system, (b) little to no pressure from the ministry to continue improving teacher's science teaching, and (c) minimal time allocated to professional learning related to science. The perceptions that science education was not a predominate subject in Ontario's elementary education compared to numeracy and literacy was supported by the fact that the K-12 School Effectiveness Framework, under "component 4 curriculum, teaching and learning", Indicator 4.2, says: "A clear emphasis on high levels of achievement in literacy and numeracy is evident throughout the school". No other indicators focusing on high level of achievement were about science. Moreover, the Literacy and Numeracy Secretariat and the Ontario Association of Deans of Education produces research monographs throughout the year titled *What Works? Research into Practice*. As of May 1st 2016, a total of 63 monographs have been published and only two include science as a key topic whereas more than 20 include literacy as a key topic, and approximately 10 are about topics related to math. Also, as part of a larger research project published in 2014, the Elementary Teachers' Federation of Ontario conducted a study and asked teachers about

all the professional learning activities they engaged in during the current school year of the survey. Most of the time teachers allocated to professional learning time was spend on board initiated activities at 37.5%, and 14.9% of their time was spent on ministry initiated professional learning activities – which may have mostly been related to numeracy and literacy (Ontario Ministry of Education, 2014).

Due to the predominance of numeracy and literacy in the school environment, there were limited opportunities for ongoing learning in the school environment to solidify, refine or reflect on what was learned in the out-of-school activities with coaches, between teachers, or with Kristoff. As such, Anna, Elsa, and Belle’s learning may not have been refined, solidified or reflected upon as much as it could have been if teachers were provided with follow-up coaching sessions about science within the school environment and during the school day. It was clear from the professional development logs that there were no science coaches in the school environment considering that not once did Anna, Elsa, or Belle record that they “received/provided coaching or mentoring in the classroom”. The results from the logs were also consistent with the discussions with Anna, Elsa, Belle, and Kristoff about not having in-situ science coaches. The concept of Anna, Elsa, and Belle not having ongoing learning with science coaches who could have provided regular feedback and the opportunity for teachers to reflect on their science learning was contrary to reform-based professional learning. Pritchard and McDiarmid (2005) explained that reflective practice is one of the main elements needed for effective teaching and professional learning. Also, Guskey (2002) argued that, “if the use of new practices is to be and changes are to endure, the individuals [teachers] involved need to receive regular feedback on the effects of their efforts” (p. 387). Generally, Ingvarson et al. (2005) discussed that the types of professional learning linked to improved outcomes have provided opportunities for teachers to engage in pedagogical dialogue and critical reflection and receive feedback. In this capacity, although Anna, Elsa, and Belle perceived that their engagement in the CPL related to science helped to improve their inquiry-based science teaching and the learning needs of their students regarding science, without having followed-up or time to reflect on their learning within the school once the out-of-school CPL opportunity was complete, their learning may not have been as effective as it could have been.

In addition to not having science coaches in the school environment, rarely did Anna, Elsa, and Belle engage in CPL related to science within the school day. The one form of in-situ collaboration with regards to science education that Elsa and Belle spoke about happened in passing, in the photocopying room or when one quickly went into the others classroom to ask a specific question: “hallway chatting”. Recall that Belle and Elsa valued this type of collaboration about science because it was convenient and it was about a specific question about a student or a concept; thus, it was tailored to their specific needs in the classroom. Note that there was a discrepancy between the results from the professional development logs and the teachers’ narratives about their hallway chatting. The logs failed to reflect the amount of hallway chatting they engaged in because as Belle expressed, they forgot about the conversations by the time they reached their classroom because they moved on to completing other tasks. Regardless, research has identified benefits of the unplanned, hallway discussions that related to the experience of Elsa and Belle. For example, Elsa and Belle brainstormed ideas and provided each other with constructive feedback. In turn, they were more likely to successfully implement what they learned from the CPL activities (Cochran-Smith & Lytle, 1999). It was unknown whether the hallway collaboration was the most preferred learning interaction between Elsa and Belle but McLellan (1996) said that the most preferred and common learning interactions between colleagues occurs spontaneously through informal interactions and observations. Either way, the hallway collaborations were embedded in the context of the task and were tailored to Elsa and Belle’s level of science knowledge – aligning with Situated Learning Theory (Lave & Wenger, 1991). Lastly, the hallway collaborations between Elsa and Belle aligned with the concept that the interaction and relationship between teachers is a key aspect to coherence which was identified as a key characteristic of CPL in general by Desimone (2009).

Besides the hallway collaborations, CPL related to science within the school environment was not a regular or ongoing occurrence even though the School Effectiveness Framework suggests that “knowledge and effective evidence-based instructional practices are shared (e.g., through co-planning, co-teaching, mentoring, inquiry and coaching)” (Section 2.4). For instance, Anna reported that she engaged in only one collaborative activity before school with her science learning coordinator.

During the school day, Anna, Elsa, and Belle recorded on their professional development logs a total of five instances whereby they collaborated about science during their preparation time. Anna, Elsa, and Belle expressed that they did not use their preparation time to focus on science collaboration because they focused on numeracy and literacy. For instance, Anna had to prepare her students for EQAO testing. The narrow focus of EQAO tests has also been acknowledged by the Elementary Teachers' Federation of Ontario as they said the "emphasis on EQAO tests means less time is spent on other subject areas, such as science" and moreover, EQAO "testing drives all the student learning and teacher professional learning that goes on in their school" (Brand, March 2010). The issue of not having time to focus on science education was also echoed by Cotabish, Dailey, Hughes and Robinson (2011) who went so far to say that "unfortunately, research suggests that science is virtually ignored in the elementary grades" (p. 16) because of the lack of time.

Research Question Four: What initiatives has the school principal taken to engage teachers in CPL for science?

The response to the question is organized into three components: (a) characteristics related to Kristoff's leadership that affected Anna, Elsa, and Belle's engagement in CPL related to science, (b) the organization of the Grade 4-10 Transitions and Pathways Collaborative Inquiry project, and (c) ministry factors that influenced the in-school initiatives that Kristoff created to promote teacher collaboration and to use those opportunities for science education.

Kristoff's leadership influencing teacher CPL related to science. The influences that affected Anna, Elsa, and Belle's engagement in CPL related to science within the school setting from the perspective of the Kristoff parallel other researchers findings. For instance, Leclerc et al. (2012) studied influences affecting elementary teacher engagement in CPL within the school environment in general, and related the factors to the school principal. They found four important factors involving principal leadership: (a) encouraging teachers to engage in CPL activities, (b) supporting and providing follow-up for questions, (c) creating time for meetings, and (d) including teachers in decision making.

First, Leclerc et al. (2012) interpreted encouragement as the principal motivating and being positive about teacher engagement in CPL. In the case of Kristoff, he was greatly supportive of Anna, Elsa, and Belle’s voluntary engagement in CPL related to science so that students can have a better learning experience. To lead by example, Kristoff demonstrated the “importance of continuous learning through visible engagement in [his] own professional learning” on an ongoing basis, as suggested in the Ontario Leadership Framework under the section “Building Relationships and Developing People”. Overall, Kristoff’s actions were creating a school culture that supported professional learning, even for science education. The culture is vital considering that the culture of the school may have a greater influence over teacher learning than professional learning activities or programs – as mentioned by Luft and Hewson (2014) who wrote about elementary science teaching. Overall, Kristoff’s encouragement for teachers to pursue further learning is a trait of strong principal support and leadership that helps shape the culture and school development, and is a valuable component to professional learning and reform change (Rinke & Valli, 2010). Secondly, Leclerc et al. (2012) found that supporting and providing follow-up for teacher questions was an important component of principal leadership. For instance, if teachers wanted resources, they hoped that the principal would purchase those resources to use with their students. Or, if teachers had questions following a learning session, they hoped that the principal would make time to address those questions in nearby meetings. In this research, Kristoff provided Anna, Elsa, and Belle money for resources to conduct science investigations with their students whenever they asked – he was supportive of teachers implementing their learning in their classroom practice from the out-of-school CPL activities related to science. However, due to the provincial mandates focusing largely on numeracy and literacy, Kristoff struggled with making time to address questions related to science during nearby staff meetings. Science was not the most pressing subject to address and it was not something that was generalized to all teachers. Thirdly, Leclerc et al. (2012) highlighted the concept of creating time for meetings: “having time set aside during school hours for collaborative meetings is a crucial organizational factor” (p. 6). Recall that Kristoff created common preparation blocks and academic teams that were also recommended by researchers (e.g., Schnellert, Butler, & Higginson, 2008) to have

teams of teachers collaborate to plan, set goals, reflect, assess student achievement, and adjust their instructional practice. The issue was that although common preparation blocks and academic teams were created, that time was hardly used for science education because of the predominance of literacy and numeracy on teacher's accountability and workload. Moreover, due to the teachers' Collective Agreement, Kristoff was unable to tell the teachers to collaborate or take part in any tasks during the preparation time. Lastly, Leclerc et al. (2012) found that involving teachers in decision making was important. Teachers wanted their voice to be heard by the principal so that they saw and noted that their input made a difference in the decisions the principal made. Leclerc and colleagues are referring to a bottom-up leadership style that Kristoff enacted. Recall that Kristoff made release days optional and teachers were able to decide what subject they wanted to focus on as long as it was aligned with the School Effectiveness Framework. According to Kristoff, science was not included in the School Improvement Plan because it did not align with the Board Improvement Plan for Student Achievement. In fact, science is not mentioned in the Board Improvement Plan. Meanwhile, literacy and numeracy are both mentioned once. However, Kristoff valued science, and he allowed teachers to pursue science professional learning on release days if they chose to do so. It turned out that no teacher in the school, including Anna, Elsa, or Belle used their release time to focus on science. Recall that the Student Achievement Division from the Ontario Ministry of Education supported the Grade 4-10 Transitions and Pathways Collaborative Inquiry project and the Science Task Force and the Sector Projects were supported by the school board. So, the teachers used their release time to focus on other learning activities such as the Universal Design for Learning model. Also, considering that accountability measures for science were not as stringent compared to literacy and numeracy, it is possible that there was little incentive to participate in CPL related to science unless the teacher was intrinsically or extrinsically motivated. The idea of not being intrinsically or extrinsically motivated may be a reflection of the larger elementary teaching body in Ontario as 67.3% of teachers in Ontario said that a barrier to their participation in professional learning in general was that there was minimal incentive to participate in the activity (Ontario Ministry of Education, 2014).

Leading with the bottom-up leadership style and its effects on professional learning and the school have been debated. According to van Driel, Beijaard, and Verloop (2001) and others, bottom-up leadership is preferable because the top-down approach to curriculum implementation often results in failed reform: “over and over again, these reforms fail, and these failures are laid at the feet of the teachers who were asked to do the challenging task of implementing the reforms” (Garii, 2006, p. 83). On the other hand, Lowe and Appleton (2015) expressed that with bottom-up leadership styles, professional learning is “left up to individual teachers to decide what they want to improve in and to then seek out a workshop, course, or other means to improve their skills and knowledge. This leaves schools and teachers with ad hoc training in a range of different areas” (p. 847). Lowe and Appleton’s remark was true in terms of science education with the study participants. Only Anna, Elsa, and Belle chose to spend time on science. During the discussions with the teachers, they noted that other teachers chose not to progress their learning about science and learn about DRiVe, nor did they teach using the DRiVe model in their classroom instruction. As a result, Anna, Elsa, and Belle did not have other teachers to collaborate with about science within or across their academic teams because of the different teaching styles. Referring back to Lowe and Appleton’s remark, the combination of Kristoff’s bottom-up leadership and the lack of emphasis on science from the school board and ministry may have been sufficient reason for teachers to not focus on professional learning related to science. This was ultimately a disadvantage to teachers such as Anna, Elsa and Belle who were interested in science because it limited their in-school science collaboration from a lack of teachers to collaborate with.

The organization of the Grade 4-10 Transitions and Pathways Collaborative Inquiry project. Whitworth and Chiu’s (2015) statement: “leaders who benefit from consistent professional development themselves may be more proactive in facilitating effective professional development” (p. 130) for his/her teaching staff related to Kristoff. Kristoff sought “out relevant professional learning and resources to support educators” (School Effectiveness Framework, Section 2.4). For example, Kristoff sought out, initiated, and headed the Grade 4-10 Transitions and Pathways Collaborative Inquiry project whereby Anna, Elsa and Belle collaborated with the nearby high school science

teachers to learn how to better prepare their students for high school science. So, Kristoff played an important role in science education reform at the public school by connecting Anna, Elsa, and Belle with resources to improve their science teaching (Spillane, Diamond, Walker, Halverson, & Jita, 2001) and by being “engaged in professional learning with staff” (School Effectiveness Framework, Section 2.4). The concept of the school principal engaging in professional learning with their teaching staff was also highlighted by Brownlie and colleagues (2011). Kristoff’s actions with the Grade 4-10 Transitions and Pathways Collaborative Inquiry project were parallel to what the Ontario 2007 revised curriculum for science and technology stated about the roles and responsibilities of principals: “to enhance teaching and student learning (...) principals promote learning teams and work with teachers to facilitate teacher participation in professional development activities” (p. 8). Also, his leadership on the project aligned with the Ontario Leadership Framework and its conception of promoting a collaborative learning culture by “enabling schools, school communities and districts to work together and to learn from each other with a central focus on improving teaching quality and student achievement and well-being” (p. 8). Lastly, the fact that Kristoff initiated this project and teachers altered their science instruction based on their learning; it supported others researchers (e.g., Banilower et al., 2007; Corcoran et al., 2001) who have claimed that school leadership plays a critical role in improving science teachers’ instruction through professional learning and other administrative practices.

Ministry factors that influenced other CPL opportunities related to science from Kristoff’s leadership. Besides the Grade 4-10 Transitions and Pathways Collaborative Inquiry, the remainder of Kristoff’s initiatives to engage teachers in CPL were not directly related to science education. Two two main reasons were: (a) science was not a priority in elementary education, and (b) Kristoff was limited by the teachers’ Collective Agreement. Although the creation of academic teams and teachers having common preparation time aligned with several board requests and the research literature, the academic teams usefulness for science education was limited by the teachers’ Collective Agreement in the sense that Kristoff could not tell the teachers what to do during that time. For example, it is in the Collective Agreement that teacher preparation time is not for meetings (e.g. meetings for: common planning, teacher performance

appraisal and evaluation, parents, administration, etc.), and teachers are *not* obligated to coordinate and use common time together. Thus, from the perspective of Kristoff, the issue of not having enough time for ongoing CPL regarding science within the regular school day was that the time to collaborate is not mandated in the teachers' Collective Agreement. Therefore, as Kristoff questioned, "now what do you do to facilitate it [teachers' CPL]?"

The two reasons about science not being perceived as a priority in elementary education, and Kristoff being limited by the teachers' Collective Agreement were not unique to this research. The first reason for science not being predominate in Ontario's education was supported by Halverson and colleagues (Halverson et al., 2011) who paralleled Kristoff's opinions when saying: as the local leaders "gauge competing pressures to improve different areas of the instructional program, science reform seldom emerges as the top priority (even as international comparisons push science as a national priority)" (p. 412-413). Moreover, this was a reason for the lack of congruency between Kristoff's push for strong reform-based practice regarding science and the need to improve student achievement in science. As Kristoff expressed, reform efforts have been worked to reshape mathematics and language arts instruction in response to the standardized tests, and schools have increased the allocated teaching time for mathematics and literacy instruction but have reduced the resources available for science (Halverson et al., 2011). Next, Kristoff's perceived limitations stemmed from the teachers' Collective Agreement. Recall that Kristoff established an internal support system in the school environment that aligned with the School Effectiveness Framework, Section 2.4: he created "conditions (time to meet and talk, common planning time) that promote collaborative learning cultures" by creating academic teams. The teams also aligned with the School Effectiveness Framework, Section 2.1 as they promoted teacher "collaborative learning, inquiry, co-planning and or co-teaching [to] inform instructional practice to meet the needs of students" and to build "capacity to strengthen and enhance teaching and learning". The creation of academic teams met the suggestions from: (a) the Ontario Leadership Framework for the principals to create "a structure of teams and groups that work together on problem solving" (under section titled, developing the organization to support desired practices); (b) the Ontario Ministry of Education, 2007

revised curriculum for science and technology which states that school principals are responsible for promoting teachers “learning teams” and to assist teachers in their participation in professional learning; and (c) the research literature suggesting that for principals to support teacher learning, principals should provide teachers with scheduled time for uninterrupted meetings, space, resources to support their ideas, encouragement, and professional learning (e.g., Ermeling, 2010; Richardson, 2007; Slavit et al., 2010).

Research Question Five: What factors contribute to, or hinder, teacher CPL related to science?

To address the research question without being repetitious with what has been said above, only additional influences on teacher engagement in CPL related to science are discussed.

Limited time for CPL about science. The lack of time for CPL about science was addressed throughout the research findings and discussion. Thus, an additional reason for why Anna, Elsa, and Belle may have valued CPL related to science was not only because it helped improve their science teaching, their participation was perceived to have helped reduce their planning time for science. The teachers did not have to independently develop lessons and the collaborative input into designing lessons was perceived as helpful because different ideas were put forth that may not have otherwise been developed if lessons were planned independently. Their collaboration provided an opportunity to learn about “how others do similar tasks in their classrooms” (Belle), so they learned about “more ideas that you don’t have to seek out on your own” (Elsa) and could apply to their classroom teaching. The concept of having time to share ideas with one another was important considering that the second greatest inhibitor to their science teaching was the time available to plan and prepare for science lessons. Anna, Elsa, and Belle were classroom teachers who were responsible for preparing for all core subjects to their homeroom students so the time they could spend planning for science alone was limited. Similarly, other research studies investigating elementary school science teachers found that teachers were concerned about the time to prepare for science instruction and time in general for science education (e.g., Dailey & Robinson, 2016; Lowe & Appleton, 2015). In terms of Lowe and Appleton’s (2015) study, the teacher participants were concerned about the time for teacher professional learning in order to discuss the

curriculum and inquiry pedagogy, and they were concerned about the lack of time they had to plan for teaching and to access the required materials to teach with while applying inquiry teaching strategies. The elementary teachers in Lowe and Appleton's (2015) study expressed that "there was no specific time devoted to science planning and preparation within teams or year levels unless it was teacher-initiated in their own time" (p. 854).

Limited number of teaching partners to collaborate about science. Recall that Anna, Elsa, and Belle spoke about how they felt as though there were a limited number of teachers to collaborate with in the school setting because the majority of teachers did not share similar teaching styles for science - using the DRiVe model. As such, Anna, Elsa, and Belle perceived their collaboration to be limited to their respective academic teams at the elementary school. However, these perspectives were contrary to an argument presented by Brownlie, Fullerton, and Schnellert (2011) who said: "Teachers do not have to teach in similar styles to coordinate what they do and to reinforce key concepts, thinking skills and approaches" (p. 30). It may have been that Anna, Elsa, and Belle were not open minded or willing to work with other teachers on their team or across teams to teach others about the DRiVe model and why science should be taught through inquiry. Reasons may have included not having enough time during the school day, not being in close enough proximity to other teachers to regularly collaborate with them considering the large size of the school, or not wanting to take on the leadership role of educating other teachers to eventually develop shared instructional strategies across the school for science education.

Teacher beliefs. In relation to Lave and Wenger's (1998) theory of Situated Learning, the teachers should theoretically progress toward a "full participant" as they actively engage in and become enculturated in the Community of Practice related to science – whether that was the community from the Science Task Force, the Sector Projects, or amongst themselves at the elementary school. Lave and Wenger (1991) did not propose how long it could take for teachers to progress from a beginner to a full participant. Nevertheless, Anna, Elsa, and Belle believed that regardless of the number of years they had been teaching, regardless of whether they were considered a beginner or experienced teacher according to the Ontario Ministry of Education, and regardless of

how long they actively engaged in a community within various Sector Projects, the Science Task Force, or amongst one another within the school environment, they felt as though they would always remain a legitimate peripheral participant (beginner) in a community. The reason was that each teacher perceived science to be dynamic in nature: science was an evolving subject that requires refining, reinterpreting, and coming to new understandings about how to teach science. Given this, Anna, Elsa, and Belle perceived that they could not and would not become experts at teaching science.

In terms of believing that science is dynamic in nature, Anna, Elsa, and Belle were attuned to the fact that investigations included several variables that could be altered, and that different students could think of altering different variables. Consequently, science was not a subject that could be taught and learned in a similar manner year after year as different students could treat investigations differently. As Elsa expressed, science is unlike math where “a triangle is a triangle” and regardless of the students, the triangle will forever be a triangle. Thus, Anna, Elsa, and Belle believed that they would not become an expert science teacher, regardless of their ongoing participation in CPL activities regarding science because (a) science is an evolving subject, and (b) the concept of investigations change depending on the students. The two reasons parallel researchers who believe that when addressing teacher beliefs, they cannot be separated from the context in which they occur because they are situational (e.g., Fives & Buehl, 2012; Chant, 2009; Levin et al., 2013). Anna, Elsa, and Belle believe science is situated based on their particular students who create a different social and cultural environment – as beliefs are also influenced by the social and cultural context that teachers engage in daily (e.g., Beijaard et al., 2004; Fairbanks et al., 2010). In addition, Anna, Elsa, and Belle’s opinion that they would not become expert science teachers because science is constantly changing aligns with their beliefs about science teaching and learning. Based on the Beliefs About Reformed Science Teaching and Learning questionnaire, each teacher held a reformed perspective about teaching and learning science that is theoretically underpinned by social constructivism. Anna, Elsa, and Belle’s beliefs appeared to be congruent with the definition of the nature of science as written in the Ontario 2007 revised curriculum for science and technology: “science is a dynamic and creative activity (...) Scientists continuously assess and judge the soundness of

scientific knowledge claims by testing laws and theories, and modifying them in light of compelling new evidence or a re-conceptualization of existing evidence” (p. 4). For instance, Anna, Elsa and Belle believed that science was learned and taught through inquiry-based investigations whereby they used constructivist-based, collaborative activities to engage students in asking questions and planning procedures, then record observations, organize the data and draw conclusions to then communicate their findings – aligning with the Ontario 2007 revised science and technology curriculum.

Anna, Elsa, and Belle’s reform-based beliefs about science learning and teaching were consistent with the type of activities they engaged in during the out-of-school activities (Science Task Force and Sector Projects). Given that the teachers implemented the inquiry-based investigations into their classroom teaching as often as possible, their actions supported the notion that their beliefs about the nature of science and the learning and teaching of science can act as a filter as to whether and how teachers enact reform-based instructional strategies in their classroom practice (Sampson et al., 2013). However, the teachers felt that the implementation of inquiry-based instructional strategies was influenced by external factors that hindered the relation between teaching beliefs and instructional strategies implemented in the classroom - as suggested by Buehl and Beck (2015). Anna, Elsa, and Belle felt that they were unable to facilitate inquiry-based investigations all the time, or as Kristoff hoped for with the 80/20 model whereby 80% of the class students complete hands-on learning activities and the remainder 20% of the class was teacher-centered, traditional teaching. Anna, Elsa and Belle felt that they needed to use traditional teaching strategies because: (a) not all students knew how to engage in DRiVe activities, (b) students needed help to consolidate and draw conclusions about their investigations, and (c) the teachers needed to help their students understand the theory behind the activity. The teachers believed that the three scenarios above arose from the fact that some of their students were not prepared for DRiVe investigations because their previous teachers taught science from textbooks rather than hands-on investigations - about half of their students’ knowledge and skills about DRiVe had not been developed as they progressed through each elementary school grade. Based on the narratives from Anna, Elsa, and Belle, not all elementary teachers voluntarily engage in CPL related to science education to be able to guide students through the scientific

inquiry/experimentation skill continuum outlined on in the Ontario 2007 revised curriculum for science and technology using the DRiVe model. The reason is that there is no push from the ministry to engage and learn the DRiVe model. Thus, Anna, Elsa, and Belle found themselves learning how to teach the DRiVe model along with providing students with a platform to engage in the activity if they were considered to be competent or proficient on the continuum for scientific inquiry and experimentation skills.

Chapter Summary

Given the complex nature of Ontario's elementary education, this research identified the interconnectedness of three overarching concepts that emerged from the participant data and infiltrated multiple themes discussed in the research findings.

1. The lack of emphasis on science in Ontario's elementary education
2. The limited time available for CPL about science
3. The limited number of teaching partners to collaborate about science

The selected insights predominantly influenced elementary teacher engagement in CPL related to science, which then made way for the broad implications, study limitations and future recommendations that are discussed in the next chapter.

CHAPTER VII: RESEARCH IMPLICATIONS, LIMITATIONS, AND FUTURE RECOMMENDATIONS

Research Implications

This single qualitative case study provides a snapshot of elementary teachers and their school principal's multiple and competing views about personal and contextual factors affecting teacher engagement in collaborative professional learning as this related to science education within the school environment. By placing teachers and their administrator at the centre of this research, they were central to understanding the nature of collaborative professional learning within the elementary school model and were key to better understanding the affordances and constraints associated with this enactment. This study was viewed through the lens of Situated Learning Theory (primarily discussed by Lave and Wenger, 1990) for the reasons that viewing knowledge under the situated theory has implications for understanding teacher learning and the design of instructional activities. The research findings and the synthesis of the findings for each research question brought forth research implications that are interrelated to the idea of including instructional science coaches as a component of collaborative professional learning situated within the school environment:

- Part One: Ongoing learning with instructional science coaches embedded in the school is necessary for inquiry-based skill transfer to the classroom for improved student achievement.
- Part Two: Strategies to include instructional science coaching as a component of collaborative professional learning related to science situated in the school environment.
- Part Three: Benefits of including science in the School Effectiveness Framework K-12, and having time for collaboration in teachers' Collective Agreement include the potential of having instructional science coaches as a component of collaborative professional learning that is ongoing within the school environment.

The purposes of addressing the research implications are to help to: (a) tailor ongoing collaborative professional learning within a school setting by understanding and adapting to contextual factors to support science teacher engagement in collaborative professional learning and their science learning and teaching; (b) bridge the gap between theory-driven academic endeavors about the process of how teacher science learning occurs via collaborative professional learning, and current practice-oriented approaches; and (c) open the lines of communication between educational science researchers, school administrators, and teachers alike to help align goals and improve efforts to strive for effective participation in collaborative professional learning to improve Ontario's science education. Note that there are multiple ways to interpret qualitative data as it is subjective in nature. My interpretations of the data have been thought about in depth, greatly reflected upon, and have been discussed in relation to the research literature and theoretical perspectives. I acknowledge that my personal background discussed in the introduction of this study (see Chapter I) may have colored the discussion.

The limitations of this study are outlined according to ones related to the research participants and the research methodology. Lastly, I will conclude with a series of recommendations for future research on this phenomenon. I recommend a number of modifications to the current study to develop a more in-depth understanding of teacher engagement in collaborative professional learning regarding elementary science education, how teacher engagement translates into their teaching practice, and how it influences their student's science learning.

Part One: Ongoing learning with instructional science coaches embedded in the school is necessary for inquiry-based skill transfer to the classroom for improved student achievement.

This research study adds to the existing literature explaining that it is necessary to move forward from the common “train and hope” philosophy (Sparks, 2002) of short-term and/or one-time form of professional learning. As much as professional learning can improve teacher knowledge of inquiry and the skills involved in inquiry teaching (Haney, Wang, Keil, & Zoffel, 2007; Vanosdall, Klentschy, Hedges, & Weisbaum, 2007), this learning does not necessarily translate into teachers altering their instruction in the classroom to suit learners needs (Desimone, 2002; Opfer & Pedder, 2011) or to improve

student achievement (Desimone, 2002; Joyce & Showers, 2002; Yoon et al., 2007). For example, Anna, Elsa, and Belle highlighted that the professional learning that occurred during the professional activity days – a form of traditional professional learning - was often made without references to situated problems of classroom life (Hattie, 2008) and failed to distinguish between different teaching styles, schools or classroom contexts, or the individual needs of teachers (Boyle et al., 2005). In this capacity, with the “demands for improved science education, teachers, administrators, and school districts are facing the dilemma of adding quality science instruction to their already full day” (Dailey & Robinson, 2016, p. 139), this research study found that there needs to be the development of effective collaborative professional learning activities situated in the school environment that includes instructional science coaching to support effective teaching practices, and in turn, student learning outcomes (e.g., DeMonte, 2013; Yoon et al., 2007) for science education – especially considering that teachers need to have the knowledge and skills that are embedded in the new curriculum (Akerson et al., 2009; Kimble, Yager, & Yager, 2006) and in this scenario, from the Ontario 2007 revised science and technology curriculum. The implementation of new reform-based science curriculum often requires teachers to make adjustments to both their understanding of subject matter and to their learning and teaching of science. Without the support of instructional science coaches, teachers are inclined to become frustrated and return to previous methods of teaching (Fraser, 2007), particularly when elementary teachers are mostly classroom or general teachers who do not know how to successfully teach inquiry (Bybee & Fuchs, 2006). Chen et al. (2015) explained that providing teachers with training, resources, and personalized feedback within their working context may be the most effective way to generate changes to teacher practice and beliefs about science education. Harris and Jones (2010, 2011) also emphasized that learning from collaborative professional learning activities related to science must focus on the teacher and work relentlessly to improve teacher pedagogy so that student needs are effectively met. As such, based on the findings from this research study along with suggestions from Chen and colleagues, and Harris and Jones, elementary teachers who teach science need to be guided by an instructional science coach. For instance, while Anna, Elsa, and Belle took part in the Science Task Force and the Sector Projects where they were accompanied by

instructional science coaches, they found those activities to be the most effective collaborative professional learning related to science education. Anna, Elsa, and Belle's learning was focused on inquiry processes and the transfer of knowledge and skills learned in the collaborative professional learning activities to their classroom practice. So, the instructional science coaches met the teachers' needs by being responsive to their specialized needs while maintaining an objective view of the big picture of elementary science education.

Instructional science coaching is the focus of the research implication. Beyond the research participants expressing their desire for instructional science coaching, Habegger and Hodanbosi (2011) suggested that instructional coaching is the best model of coaching as it provides "ongoing training that addresses the issues teachers face daily in their classrooms and is aligned to state standards, curricula, and assessments" (p. 36). Sailors and Shanklin (2010) described instructional coaching as "sustained class-based support from a qualified and knowledgeable individual who models research-based strategies and explores with the teacher how to increase these practices using the teacher's own students" (p. 1). Additionally, Taylor (2008) said that instructional coaching is a form of instructional leadership "characterized by non-supervisory/non-evaluative individualized guidance and support that takes place directly within the instructional setting ... intended to promote teachers' learning and application of instructional practice (p. 13). The most commonly referenced components of instructional coaching were highlighted by Knight (2006): equality, choice, voice, dialogue, reflection, praxis, and reciprocity. Generally, roles served by the coach include modeling lessons, observing with feedback, supporting teachers, and developing the teacher's capacity to reflect on instructional practice (Walpole & Blamey, 2008). For the teacher, coach-encouraged self-reflection provides the necessary scaffolding toward independence from the coach as the teachers practice identifying their own strengths and areas for improvement (Collet, 2012; Powell, Diamond, Burchinal, & Koehler, 2010). One of the ultimate goals of coaching includes developing the teacher's ability to independently reflect, make instructional decisions, and determine the effectiveness of instruction so that they can adjust future lessons (Knight, 2007) to improve their instruction and student learning. The concept of reflection is a central component of situated learning because it evokes interpersonal

insights and fosters teacher's revising their current understandings (McLellan, 1996). Reflection enables teachers to compare their understanding of a concept, and the application of the concept using inquiry-based procedures with the understandings from a coach and/or other teachers, particularly within the community. The process of having teachers reflect on their instructional practices was noted in previous research as supporting the transformation of new skills and strategies into the teachers' classrooms (Cantrell & Hughes, 2008; Lotter, Yow, & Peters, 2013). Cantrell and Hughes (2008) further noted that to be an effective element of change, self-reflection on teachers' abilities is essential.

Anna, Elsa, Belle, and Kristoff's enthusiasm for instructional science coaches to be included in collaborative professional learning occurring in the school environment has been echoed in the research literature. In 2009, Cornett and Knight found that teachers only implement their newly learned teaching strategies from common summer workshops 15% of the time. Meanwhile, if the professional learning is followed with instructional coaching, teachers successfully implement newly acquired teaching strategies upward to 85% of the time. Moreover, the authors expressed the positive impact of coaching on teacher attitudes, teaching practice, and efficacy. Similarly, Knight (2006) found that with instructional coaching, there was a 70% increase in teacher implementation of new instructional practices. This demonstrates that coaching and professional learning need to go hand-in-hand. Driscoll (2008) highlighted that coaching is not an independent construct. Coaching is well-documented in the research literature as a component of professional learning that helps to build teacher skills and facilitates effective implementation in education (Houston, 2015; Reinke, Stormont, Herman, & Newcomer, 2014). Although there has been sufficient evidence to support the benefits of instructional coaching, particularly for numeracy and literacy, coaching in science is rare (DeChenne et al., 2014; Kraus, 2008). Descriptive research shows that science coaching may help elementary and middle school teachers implement inquiry-based instruction and may have an effect on student achievement in science (e.g., Bransfield, Holt, & Nastasi, 2007; Dempsy, 2007). More recently, DeChenne et al. (2014) conducted a descriptive case study using mixed methods. The participants included seven science coaches and nine elementary teachers engaging in a summer professional learning experience that

continued into the teacher's classroom during the school year. Like Anna, Elsa, and Belle, the teacher participants felt that the instructional science coaches helped to develop and clarify their understanding of inquiry and improved their science classroom instruction by helping create inquiry lessons. In terms of the relationship between the amount of time the teacher and coach spend together and improvements in teacher practice, there is limited research attempting to identify a duration of coaching necessary to promote change, particularly in science teacher practice. For instance, Anderson, Feldman, and Minstrel's (2014) five-year mixed methods study on science coaching reported a strong relationship between the amount of time the teacher and coach spend together and improvements in teacher practice. The study quantifies the time to be "at least 10 hours for elementary teachers" (p. 2). Also, Houston's (2015) research found that it took a minimum of 8-9 sessions between an instructional science coach and a science teacher for the teacher to effectively implement inquiry-based approaches in their classroom practice for an inquiry unit.

From a theoretical standpoint, the social learning aspect of Situated Learning by Lave and Wenger (1991), and Wenger's (2000) community of practice connects to the research implication of including instructional science coaches in the school environment as a component of collaborative professional learning for science. Having instructional science coaches within the school environment abides by Situated Learning theory, considering that from this lens, collaborative professional learning related to science cannot be isolated from the complex interplay of teachers and their social teaching environment; their learning must be situated in the context it will be applied for it to be effective (Lave & Wenger, 1991). Therefore, with instructional science coaches in the school, there is a function of social learning between a coach and a teacher in relation to the teaching environment, including its cultural norms. The learning interactions that can occur between a coach and a teacher also abides by Wenger's (2000) definition of a community of practice: a group of individuals with a shared interest, who engage in learning activities with one another while building trustworthy relationships. The learning activities between the instructional science coaches and the teachers include sharing resources, tools, knowledge and stories. The overall benefit of the interactions between the teacher and coach would be that the teachers would formulate new or refined ideas,

strategies, and/or reflections about his/her science teaching and instruction, and the coach may learn new ideas and approaches about how to best support teachers learning. In terms of the social learning process, the teachers would socially engage in learning through collaborative conversations with the instructional science coach. The learning would occur just as Anna, Elsa and Belle's did by assuming the role of the beginner learner or the legitimate peripheral participant and the instructional science coach taking the role of the expert. With these roles, teachers are able to first watch an investigation performed by the instructional science coach to develop tacit knowledge. Then, teachers can take part in the task while engaging in discussions with the instructional science coach and fellow teachers to address questions and concerns and reflect on their learning. As more complex skills are developed, teachers can perform and understand tasks with decreasing levels of support from coaches (McLellan, 1996). Also upon practicing investigations with a coach, skills are developed, refined, and extended to more complex skills that can be transferred to other relevant and applicable situations. Lastly, with the assistance of a coach, the teachers gain confidence in their science learning and teaching and may further engage with one another in more activities regarding the content being learned and develop a language and belief system amongst the group of learners - engaging in the process of enculturation.

Overall, instructional coaching is necessary for science education considering that policies call for students to become scientifically-oriented citizens and for teachers to shift toward the use of inquiry teaching strategies for learning and teaching science education (Crawford, 2014). In conjunction to what is known from the literature, it was evident from discussions with Anna, Elsa, Belle, and Kristoff that instructional coaching needs to be an integrated component of collaborative professional learning in the school environment. Borman, Feger, and Kawami (2006) who conducted a meta-analysis of instructional coaching echoed Anna, Elsa, Belle, and Kristoff in the sense that they found that the emphasis of instructional coaching is placed on "professional collaboration, job-embedded professional development, and differentiated roles for teachers" (p. 2). The aspect of job-embedded professional learning is critical as "teacher learning must occur over time as close to the classroom as possible rather than in isolated moments in time. It also means that teacher learning occurs continuously over their entire professional life

span” (Nova Scotia Department of Education & Early Childhood Development, 2011, p. 2). A problem is that it seems as though the ministry and the board are asking teachers to engage in reform-based practices for science, but have yet to provide teachers with sufficient collaborative professional learning opportunities within the school that align with what they are asking the teachers to do in their classroom, specifically, inquiry-based teaching using the DRiVe model for elementary science education. The findings from this research study identified three primary limitations outlined in the discussion chapter (Chapter VI), hindering teacher engagement in collaborative professional learning activities to learn how to teach science according to the reformed curriculum (time, predominance of numeracy and literacy, available teaching partners). Next, I will discuss strategies for incorporating instructional science coaches as a component of collaborative professional learning situated in the school environment.

Part Two: Strategies to include instructional science coaching as a component of collaborative professional learning related to science situated in the school environment.

Kristoff was greatly supportive of instructional science coaching in the school environment on a regular basis so that teacher learning in science was ongoing, refined and solidified. Kristoff’s bottom-up leadership style also provided a strong foundation to have instructional science coaches within the school environment because successful coaching within the school environment requires the school principal to have a bottom-up leadership style and involve teachers in decision-making roles (Gill, Kostiw, & Stone, 2010). However, based on the research findings, instructional science coaches were not in the school environment supporting teacher science learning largely because of the predominance of literacy and numeracy occupying time and fiscal resources. Similarly, Wayne and colleagues (Wayne, Yoon, Zhu, Cronen, & Garet, 2008) argued that sustained collaborative professional learning that includes the coaching component was financially taxing. Moreover, Wayne and colleagues argued that this approach to collaborative professional learning was the most expensive model available and may not be the most practical, even though the combination of a coach, paired with ongoing professional learning, provided direct application of training to the teacher’s classroom. Other researchers (e.g., Guskey, 1991; Garet et al., 2001) have also mentioned that effective

professional learning requires substantial resources, funding, and a clear professional learning plan. Funding an entire school for high quality continuous professional learning is costly and often outside school budgets. Regardless, Kristoff and the teacher participants believed that the education system should make changes to allocate time and resources to provide teachers with access to instructional science coaches within the school environment on an ongoing basis. Thus, this research study is one step forward amongst a debated topic to show the need to rearrange fiscal resources and time to have instructional science coaches embedded in the school environment to assist the teachers with their classroom needs. To do so, instructional science coaching as a principle component of teacher collaborative professional learning that is part of the daily routine of teachers needs to be implemented by making changes at the ministry and board level. The two main suggestions that arose from the research findings include incorporating: (a) science into the School Effectiveness Framework, and (b) time for collaborative professional learning in teachers' Collective Agreement.

The purpose of making the noted changes is that every teacher needs to be actively engaged in professional learning. For that to happen, district and school leaders need to be able to integrate collaborative professional learning opportunities into regular teaching practice rather than considered as "add-ons" to teacher workload (Belchetz & Witherow, 2014). Recall that teacher workload was the number one inhibitor to Anna, Elsa, and Belle dedicating time to their science teaching and planning; their time was primarily dedicated to tasks related to numeracy and literacy. To further support the idea that changes to board level factors need to be a step forward toward implementing instructional science coaching as a principle component of teacher collaborative professional learning that is part of the daily routine in 2011, Michael Fullan, and Jim Knight wrote the article, *Coaches as System Leaders*. In line with this research study, Michael Fullan's work is situated within the context of Ontario, and at the time of writing the article, he was the special advisor to the Ontario's premier and minister of education. Also, Jim Knight is the current director of the Kansas Coaching Project and is well known for his work on instructional coaching in education. The authors made three points that resonated with the research implication: (a) there needs to be a system change to embrace educational reform at the teacher and district level, (b) the school district needs

to focus on teachers' instructional improvement with the aid of coaching or else curriculum reform efforts will not succeed, and (c) school principals need to lead with an instructional, bottom-up leadership style as did Kristoff. Overall, Fullan and Knight expressed that the Ontario Ministry of Education, the school boards, and individual schools need to be aware that: "teachers are the most significant factor in student success, and principals are second, then coaches are third (...) the work of coaches is crucial because they *change the culture of the school* as it related to instructional practice" (p. 53). Thus, the value of coaching and the demand for coaching cannot be ignored.

Incorporating science into the School Effectiveness Framework. The 2013 K-12 School Effectiveness Framework (SEF K-12) "supports the core priorities of the Ontario Ministry of Education" (SEF K-12, pg. 3). The three core priorities include: (a) high levels of student achievement, (b) reduced gaps in student achievement, and (c) increased public confidence in publicly funded education. Thus, the focus of the framework is on the students, and then identifying supports that teachers need to meet the needs of the students. One means to support the students is for teachers to engage in "ongoing job-embedded professional learning for educators" (p. 4). The concept of ongoing professional learning is described in the SEF K-12:

Professional learning communities judge their effectiveness on the basis of results. Every educator participates in an ongoing process of identifying current levels of achievement, establishing goals to improve those levels, and working together to achieve those goals. Sustaining an effective professional learning community requires that school staff focus on learning as much as teaching, on working collaboratively to improve learning, and on holding themselves accountable for the kinds of results that fuel continued improvements. (p. 16)

Thus far, the SEF K-12 distributed from the Ontario Ministry of Education is supportive of teachers participating in ongoing collaborative professional learning to improve their learning and teaching. In fact, Indicator 4.3 states that "teaching and learning in the 21st Century is collaborative" (p. 29). The problem is that the subject of science is not specifically addressed in the SEF K-12 – unlike Indicator 4.2 that states: "A clear emphasis on high level of achievement in literacy and numeracy is evident throughout the school" (p. 27). It is apparent that there is a singular focus on numeracy and literacy, which was also apparent throughout the research findings of this study. There are

repercussions of the SEF K-12 only highlighting the importance of numeracy and literacy because the main purpose is to act as a “self-assessment tool” for individual schools (see SEF K-12, p. 3 for more detail). On page 6 of the SEF K-12, it explains that individual schools need to “review the components and indicators in the SEF K-12 and determine areas requiring attention in developing the School Improvement Plan”. The school improvement plan is “a road map that sets out the changes a school needs to make to improve the level of student achievement, and shows how and when these changes will be made” (School Improvement Plan, p. 6). Then, the School Improvement Plan is shared with the board as the individual school improvement plans have to align with the SEF K-12. Once the school improvement plan is finalized, it is necessary to plan for “professional learning based on the specific actions/strategies in the School Improvement Plan” (SEF K-12, p. 8). The point is that science is not a key priority in the SEF K-12; therefore, individual schools largely do not plan their areas of school improvement to include science, and in turn, science is not a main priority for professional learning. This was evident in the current research study, although Kristoff recognized the importance of science and encouraged and supported his teaching staff to engage in the out-of-school collaborative professional learning activities related to science.

For science to become a priority in Ontario’s elementary education, a suggestion is to first include it in the SEF K-12 so that when individual schools address what changes need to be made to better support student learning, they can include science in their school improvement plan and designate time and resources to have instructional science coaches situated in the school environment to support teacher learning and teaching. With science in the SEF K-12, individual schools can “integrate ministry initiatives and policies [including science], enhance teaching and learning [about science] and impact growth in student achievement, engagement and well-being” relate to science (p. 4). Otherwise, science may continue to be put on the backburner. Anna, Elsa, Belle, and Kristoff pointed out that there was a lack of push from the Ontario Ministry of Education for teachers to teach science using the DRiVe model. Thus, not all teachers were as interested and eager to pursue learning about DRiVe for science education. Perhaps the general view of investing time into learning about science and how to teach

inquiry-based science would shift if there were indicators in the SEF K-12 relating to science, as well as initiatives in the School Improvement Plan regarding science.

Incorporating time for collaborative professional learning in teachers'

Collective Agreement. In addition to including science in the SEF K-12, changes to teachers' Collective Agreement, which is negotiated at the board level, need to be made to encourage collaborative professional learning related to science. In particular, two areas are discussed: (a) including time for collaborative professional learning during the school day, and (b) rearranging professional activity days to better meet the needs of teacher learning.

First, currently the teachers' Collective Agreement does not designate time for teachers to collaborate during the school day. Unless designated time is included in the Collective Agreement, collaborative professional learning may continue to be thought of as an add-on to teacher workload as it may not be perceived to be valued at the board level, especially for science if it continues not to be included in the SEF K-12. Even if teachers would like to collaborate about science, they do not have the time within their work day. As Kristoff mentioned, until changes are made to the Collective Agreement to value collaborative professional learning, the ministry and board can write down that it is important and beneficial, but the writing will not necessarily translate into practice at the teacher level amongst all teachers and staff. Thus, collaborative professional learning needs to be put into the Collective Agreement so that the school principal can schedule time in the teacher timetable for collaborative professional learning, which may be used to address science also on the condition that science is included in the School Effectiveness Framework and School Improvement Plan (at the discretion of the teachers). Lastly, if time for collaborative professional learning was included in the teachers' Collective Agreement, and there were instructional science coaches regularly guiding the teachers, it may help mitigate the issue of teachers not having enough time or the proper resources to plan for and conduct science investigations. For instance, in the paper titled, *Improving student achievement in literacy and numeracy: job-embedded professional learning*, by the Ontario Literacy and Numeracy Secretariat, it was quoted that coaches can "provide all the materials teachers need to implement a strategy or routine, to help teachers transfer research into practice (...). Coaches also co-write lesson

plans, create overheads or co-teach to give teachers additional time” (Fullan, Hill, & Crévola, p. 5). Although the article was written in the context of literacy and numeracy, the same concepts could be applied to instructional science coaches for the purpose of science education.

Secondly, the teachers’ Collective Agreement includes regulating the number of professional activity days. Recall that these days were perceived by the teachers to not help them learn about and teach science using the DRiVe model. While it may seem like a financial risk to redistribute time, resources, and priorities to have ongoing instructional science coaches within the school environment to help teachers apply inquiry-based science pedagogy to their classroom practice, it is crucial to compare that risk to the fact that teachers, the main implementers of the science curriculum (Kimble et al., 2006; Roehrig & Kruse, 2005), believe the current professional activity days are largely ineffective for professional learning related to science because the priority is on numeracy and literacy. To support their perspectives, on December 18th, 2015 George Zegarac, the Ontario Deputy Minister of Education issued a memo titled, *2015-2016 Additional Professional Activity Day and School Year Calendar*. The memo discussed the amendment to the Ontario Regulation 304, *School Year Calendar, Professional Activity Days* that came into fruition on November 30th, 2015. An additional professional activity day was added in the 2015 negotiations for the Collective Agreement; each school board must designate three professional activity days and up to an additional four days per school year. Although an additional professional activity day was added, Mr. Zegarac said: “this day must be devoted to provincial education priorities identified by the Minister” (p. 1). Furthermore, specific topics outlined for Ontario’s elementary teachers included half of the day about occupational health and safety training, and the remaining half designated to “ministry priorities, specifically mathematics” (p. 2). Thus, professional activity days are taxing financial investments made by the school and district that were not beneficial to a teacher’s science learning and teaching, and in turn, their students’ science learning. For instance, in 2004, the Ontario Ministry of Education said that each professional activity day, represented \$41 million in cost to the system, and the inconvenience to students and their parents (Ministry of Education, 2004, p. 6). To put it into perspective, the three professional activity days that Anna, Elsa, and Belle believed

were not beneficial to their science teaching, costing the system, and the inconvenience to students and their parents, \$123 million dollars. Given this, the taxing professional activity days only target primarily two subjects being numeracy and literacy, while ignoring other core subjects such as science. Ignoring science in the large picture of elementary education has become problematic because based on the 2011 Trends in International Mathematics and Science Study, the science scores for elementary students have been decreasing in Ontario since 2003 (TIMSS 2011: Ontario Report). Ultimately, what is a greater risk to student learning - maintaining status quo or taking the risk of changing the current model to re-think the way professional learning is done to include a range of subjects including science? Based on the research study, it may be of greater benefit for the teachers to use professional activity days for writing report cards as that was appreciated by the teachers. As this point, the remainder of the money typically spent on the three other professional activity days could be used to pay for instructional coaches, including ones related to science so that teachers learn according to their specific classroom needs. Based on the findings, it is reasonable to believe that providing collaborative professional learning opportunities that target the specific needs of teachers would be more beneficial not only to the teachers but their students as a result of more effective teaching strategies applicable in their classroom context.

Part Three: Benefits of including science in the School Effectiveness Framework K-12, and having time for collaboration in teachers' Collective Agreement include the potential of having instructional science coaches as a component of collaborative professional learning that is ongoing within the school environment.

There are two main advantages that could arise from the discussion in part one and two: (a) promoting further collaboration over science related topics in the school, and (b) teacher consistency using the DRiVe model. First, by having instructional science coaches in the school working with teachers, it is possible that the teacher/coach interactions will spark further teacher/teacher interactions about science when the instructional science coach is not present. Not only did Kristoff mention this effect, Sun and colleagues (Sun, Penuel, Frank, Gallagher, & Youngs, 2013) identified it as the spillover effect. The authors define spillover effects as “the effects of school-based professional development on instructional practices above and beyond the direct outcome

on teachers who participated in the professional development” (p. 345). Their findings claim that the teachers who engaged in collaborative professional learning and engage in positive, collegial interactions will then talk about the topics discussed in the learning sessions with the coaches to other teachers who did not participant. Then, further learning and the encouragement to learn about science for example, may occur. Weibenrieder et al. (2015) refer to spillover as *multipliers*: “teachers who provide CPD [collaborative professional development] courses for other teachers on their own are labeled as multipliers (...) for instance, by sharing their knowledge within the faculty at their own schools and initiating collaborative work on specific tasks” (p. 28). Regardless of the definition, if science was included in the School Improvement Plan and the School Effectiveness Framework, along with time during the working day, it is probably that more collaborations would occur during the hallway sessions or more so, during preparation time. As Halverson et al. (2011) further explained:

The success of professional communities rests on the staff’s ability to share and develop their expertise. The scientific expertise of particular teachers is a critical resource for collegial interaction, and the development of new science-related knowledge and skills can provide a powerful catalyst for professional learning across the entire teaching staff. Second, experience with scientific inquiry in authentic contexts may lend teachers credibility in discussions about the relevance and advantages of a science education reform project. (p. 36)

Secondly, based on the research findings, all elementary teachers who teach science need to apply instructional strategies such as the DRiVe model so that students build their knowledge of inquiry thinking as they progress through each grade. Having instructional science coaches in the school environment may help to have consistent teaching pedagogy and in turn: (a) align classroom practice with ministry mandates, (b) help increase student learning in science from the use of hands-on investigations that can be tailored to students’ learning needs, and (c) provide greater opportunity for teachers to collaborate because everyone would be on the same page about inquiry teaching. Concerning the last point noted, it is possible that through the spillover effect or multipliers, teachers who may not hold reform or constructivist beliefs about the nature of science, would begin to modify their views as the norms of the school culture in terms of

teaching science can shift to inquiry-based teaching. For instance, Chen et al. (2015) explained that providing teachers with training, resources, and personalized feedback within their working context may be the most effective way to generate changes to teacher practice and beliefs about science education.

Limitations of the Research Study

This dissertation provides new ideas to think about when considering teacher collaborative professional learning regarding elementary science education. However, there are limitations to bear in mind, which are discussed below.

Limitations related to research participants. There are three noted limitations related to the research participants. First, generalizability was not intended as this was a single case study (Yin, 2014) with a small research sample including a total of four participants. Therefore, the results and discussions represent a snapshot of the phenomenon. They may not represent the larger population of Canadian in-service elementary teachers teaching science and their school principals, and this study does not help to understand *all* the ways in which all teachers may participate in collaborative professional learning for science. However, by way of thick, rich description and detailed information regarding the context and background of the school, Kristoff, and the teachers, knowledge could be assessed for its applicability and applied appropriately in other contexts. As Cochran-Smith and Lytle (2009) described, the knowledge generated from the participants is a local knowledge of practice. It is knowledge that can be “borrowed, interpreted, and reinvented in other local contexts” (p. 132) and can be publically shared with others such as university-based educators, researchers, and primary/elementary teachers and principals. Lastly, the diverse characteristics of the participants (e.g., years of teaching experience, grade level currently teaching, formal educational training in science) are factors that may have influenced the generalizability of the study. Secondly, Kristoff, Anna, Elsa, and Belle volunteered to take part in this study. In this capacity, the volunteers may have been prone to try something new, to change, and to be motivated to participate (Desimone, 2009). There is evidence that the most qualified teachers are the ones who seek professional learning with effective features such as content focus (Desimone et al., 2006). So, it is unclear how the findings may have been different if other teachers – not volunteers - who participated were not as

enthusiastic about science and collaborative professional learning (Bobrowsky, Marx, & Fishman, 2001). Third, teacher's work in general is multi-faceted so this study did not imply a causation between teacher's science learning and teaching from one's participation in collaborative professional learning related to science education.

Limitations related to research methodology. The teacher belief surveys were self-report questionnaires that can be subject to bias, or the inability of the teachers to accurately calibrate and report their own beliefs (Rimm-Kaufman, Storm, Sawyer, Pianta, & LaParo, 2006; Maggioni & Parkinson, 2008; Muis, 2007) because the perceptions of a situation that teachers have may be more aligned with reality than those of an independent, more objective observer (Stanovich, 2009). Also, the research methodology heavily relied on Kristoff, Anna, Elsa, and Belle describing their personal experiences and opinions, which could have been problematic because they may have completed the surveys based on perceptions of what would be a socially appropriate response (Johnson & Fendrich, 2002) instead of honestly self-reporting their own experiences. For instance, researchers (e.g., Gill & Hoffman, 2009; Judson, 2006) described that affective constructs such as epistemological and pedagogical beliefs that are constructivist in nature are socially desirable. Given this, erroneous self-reporting about teaching practice may have occurred to provide the socially acceptable response. Therefore, inferences were not made on the survey data alone. Multiple measures (focus groups, survey data, and professional development logs) were used to enhance the ability of the researcher to make a plausible and reliable inference from the data.

Secondly, the surveys about self-efficacy and pedagogical discontentment were constructs measuring affective states that are "highly personalized" (Southerland et al., 2012) and may not be representative of teachers overall self-efficacy and pedagogical discontentment regarding science teaching. For instance, for the Personal Science Teacher Efficacy scale, self-efficacy is context-dependent according to Bandura (1997). So, teacher self-efficacy for science may change depending on a particular group of students (Angle & Moseley, 2009) or the grade level being taught (Kind, 2009) for example. Or, according to Kristoff, self-efficacy may vary depending on the time during the school year (i.e., beginning of the year, report cards, EQAO, end of the year). Lastly, Anna, Elsa, and Belle's self-efficacy may be influenced by the specific unit or topic they

were teaching at the time. Thus, Anna, Elsa, and Belle may have been more or less confident in their science teaching compared to what was represented by the single self-efficacy and pedagogical discontentment surveys they filled out.

Thirdly, with regards to the professional development logs, Anna, Elsa, and Belle provided a record of events they remembered to record only when they had time available to complete the logs. As a result, the logs were not an accurate representation of their collaboration.

Recommendations for Future Research

I recommend a number of modifications to the current study to develop a more in-depth understanding of teacher engagement in collaborative professional learning regarding elementary science education, how teacher engagement translates into their teaching practice and how it influences their students' science learning.

I suggest altering the methodological approach of the current study to one that is a longitudinal multiple case study that includes a triangulation mixed methods design (convergence model). Also, the study would include over 30 teacher participants considering that at least 31 participants are recommended for the data analysis of the quantitative measures (Muijs, 2011). The purpose of this design is to “obtain different but complementary data on the same topic” (Morse, 1991, p. 122) to address the research question(s). The intent would be to compare and possibly validate and confirm quantitative data from a larger sample (over 30 participants) of participants who complete the surveys about their epistemological beliefs, self-efficacy and pedagogical discontentment related to science, with the data collected from focus group, interviews, and observations (Patton, 1990). This design would help to better understand the relationship between teacher beliefs and teacher engagement in collaborative professional learning related to elementary science education. Also, the results would be better substantiated. Lastly, with more participants from various case sites within different school boards in a province or multiple provinces, the results would be more generalizable.

There is a pressing need to conduct longitudinal research that follows elementary teachers for an extended period of time to confirm their engagement in collaborative professional learning related to science education. Furthermore, we need to better

understand how their learning from engaging in collaborative professional learning related to science education is enacted in their teaching practice. To better understand how teachers are applying their learning to their practice, and to help teachers reflect on their learning and practice, I suggest conducting in multiple observations of each participant's classroom practice to avoid the snapshot measurements. Also, I suggest video recording the teacher's classroom practice for science and have the researcher(s) collaborate with the teachers to then design and implement modifications based on their current practice. Unless teachers can see their own actions and the effects of their actions on their students in real-time, it is difficult for teachers to reflect and understand where modifications can be made to better suit their teaching to the students learning needs. Also, having teachers view their teaching may help to alter their beliefs about science.

Another reason for altering the methodological approach of the current study to one that is a longitudinal multiple case study is considering that one-time surveys about teacher beliefs (epistemological beliefs, self-efficacy and pedagogical discontentment) is not robust enough to develop a firm understanding of their beliefs. Thus, conducting a longitudinal multiple case study with more than 30 teachers who complete multiple surveys throughout the study is necessary to develop a greater understanding of the teachers themselves, and to be able to claim greater generalizability. Having the teachers do multiple surveys about their beliefs is also preferable considering that beliefs are malleable in nature and operate along a continuum (Fives & Buehl, 2012). As such, conducting multiple surveys about teacher beliefs across different units that are taught throughout the school year would yield more robust findings.

A third reason for implementing the suggested methodological approach is that it would give the research time to develop a strong rapport with the teachers and their principal. One purpose for this is for the researcher(s) to take a more active role with the teachers in the sense that they work alongside the teachers to provide their expertise on the science subject matter where possible – act as a coach or a mentor to the teachers. The reason is that as Michell (2002) explained, “collaboration with academics can be very helpful, provided both groups [teachers and academics] recognize that they bring different and equally valuable expertise and ways of thinking to the partnership – that each has much to learn from the other” (p. 253). Moreover, “it is through this notion of

partnership that science teacher learning stands out as defining new ways of recognizing, acknowledging, and building on teachers' professional knowledge of practice” (Loughran, 2014, p. 820).

Another study that deserves attention in the near future is a descriptive study addressing elementary science teachers' perceived conception of having instructional science coaches aiding their science learning, classroom practice, and student management within the school environment on an ongoing basis in the same school board as the present study. It would be beneficial to illuminate the potential beneficial outcomes of having the in-house instructional science coaches on a regular basis to help demonstrate the need to redistribute fiscal resources and time to accommodate for the instructional science coaches within the elementary school. The teachers could maintain a portfolio with reflection logs, engage in semi-structured interviews, individually or in a group to discuss their experiences with ongoing instructional coaching within the school, and be observed by the researcher(s) to see how the coaches influence their teaching practice. The next step would be to have the teachers qualitatively describe how coaches influence their teaching practice and in turn, students science learning considering that Neumerski (2013) expressed that relatively few studies have examined instructional coaching from the teachers' perspective, and furthermore, Marsh, McCombs, and Martorell (2010) noted that “the largest gap in the existing research on coaching programs is the lack of evidence of coaching programs' effects on student achievement” (p. 877).

Delimitations of the Research Study

Although there were limitations, the narrowed study of the phenomenon in a single setting allowed for the exploration of rich and robust descriptions regarding multiple and completing viewpoints about teacher engagement in collaboration professional learning related to science education. The narrow scope of the study was in line and integral to the nature of case study research. Focusing on both teacher and principal perspectives was an important decision because it allowed for an in-depth exploration of the phenomenon, and may have led to implications for elementary teachers and leaders, and ministry level employees to see what changes could be made to teachers' collaboration professional learning in science.

Chapter Summary

With reform-based education, teacher learning should happen from participating in a culture of collaborative professional learning within the school milieu (Carlisle, Cortina, & Katz, 2011; Desimone, 2009, 2011; Dufour, 2004; Linder, Post, & Calabrese, 2012). The necessity of focusing on teacher learning through ongoing and situated collaborative professional learning is that: (a) reform in science education calls for a different portrait of science teaching and learning that many current teachers experienced themselves as learners and are currently enacting with their students, and/or (b) elementary teachers “typically have limited science backgrounds and who are responsible for teaching multiple subject areas, leaving limited time to focus on improving their science teaching” (Roth, 2014, p. 387). The two reasons echoed Anna, Elsa, and Belle concerns. Anna and Belle did not have a strong science background, and Elsa was a new teacher. Meanwhile, each teacher was overloaded with numeracy and literacy tasks. These factors may contribute to the notion of science being described as one of the most difficult school subjects (Drew, 2011; Dweck, 2006). However, teachers are expected to teach using inquiry pedagogy whereby students conduct hands-on investigations by posing questions, collecting and analyzing data, and using their learning to form evidence-based conclusions. This research drew attention to one main research implication about how “teachers need the opportunity to engage in authentic activities, participate in rigorous and critical debate within discourse communities” (Wallace & Loughran, 2012, p. 302) that included instructional science coaches within the school environment so that their learning is situated to their teaching needs.

The overarching implication put forward in this research is the provision of ongoing professional learning with in-situ instructional science coaches working alongside the teachers to further develop their science teaching strategies related to inquiry-based approaches. Step by step, preplanned, rigid instruction is not controlling teacher learning as in the professional learning activities that occurred on professional activity day days for example. The coaches respond to the moment-by-moment possibilities of the teachers’ engagement in an activity and they respond to the development of teacher understanding. Importantly, the learning is taking place within a school environment with currently available resources so that teachers learn authentic

investigations in relation to what they already know and have in their physical environment. For there to be instructional science coaches working in the school environment, there need to be alterations at both the ministry and school board levels. Starting at the ministry level, it is suggested that science is included in the School Effectiveness Framework so that when individual schools revise their School Improvement Plan, they can include science as a topic that needs to be address in ongoing professional learning. In addition, time for collaborative professional learning needs to be incorporated in teachers' Collective Agreement so that the school principal creates timetables allowing for collaboration. If science is included in the School Improvement Plan, and there are instructional science coaches in the school, it is possible that teachers would allocate more time to addressing science and learning to teach using the DRiVe model. The benefits of these changes may include more teachers across the school engaging in collaborative professional learning activities related to inquiry-based science, and expanding the network of teachers who collaborate with one another regarding science.

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Appendices

Appendix A: Western University Ethics Approval



**Western
Research**

Research Ethics

Western University Health Science Research Ethics Board
NMREB Delegated Initial Approval Notice

Principal Investigator: Dr. Jacqueline Specht
Department & Institution: Education/Faculty of Education, Western University

NMREB File Number: 105384
Study Title: Learning About Teaching Science: Improving Teachers' Practice through Collaborative Professional Development
Sponsor:

NMREB Initial Approval Date: June 03, 2014
NMREB Expiry Date: December 31, 2016

Documents Approved and/or Received for Information:

Document Name	Comments	Version Date
Recruitment Items	Email script for recruitment	2014/05/20
Other	References	2014/05/20
Instruments	Appendix I: Science Teachers' Pedagogical Discontentment	2014/05/20
Instruments	Appendix G: Teachers epistemological worldview survey	2014/05/20
Instruments	Appendix H: Science Teaching Efficacy Beliefs Instrument	2014/05/20
Instruments	Appendix F: Professional Development Log	2014/05/20
Instruments	Appendix E: Interview Questions	2014/05/20
Instruments	Appendix D: demographic questionnaire	2014/05/20
Instruments	Appendix C: Professional Development Continuum Rubric	2014/05/20
Other	Appendix A: Summary of Methods	2014/05/20
Western University Protocol		2014/05/22
Response to Board Recommendations	Response to Recommendations	2014/05/30
Instruments	Appendix I - Science Teachers' Pedagogical Discontentment_Revised_Clean Copy_PDF	2014/05/30
Instruments	Appendix H - Science Teaching Efficacy Beliefs Instrument A - Revised_Clean Copy_PDF	2014/05/30
Instruments	Appendix G - Teachers epistemological Worldviews_Revised_Clean copy_PDF	2014/05/30
Other	Appendix D - Demographic Questionnaire_Revised_Clean copy_PDF	2014/05/30
Revised Letter of Information & Consent	Appendix B: Letter of Information and Consent form Revised_Clean Copy_PDF	2014/05/30

The Western University Non-Medical Research Ethics Board (NMREB) has reviewed and approved the above named study, as of the HSREB Initial Approval Date noted above.

NMREB approval for this study remains valid until the NMREB Expiry Date noted above, conditional to timely submission and acceptance of HSREB Continuing Ethics Review.

The Western University NMREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the Ontario Personal Health Information Protection Act (PHIPA, 2004), and the applicable laws and regulations of Ontario.

Members of the NMREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

Ethics Officer to Contact for Further Information

<input type="checkbox"/> Erika Basile ebasile@uwo.ca	<input checked="" type="checkbox"/> Grace Kelly grace.kelly@uwo.ca	<input type="checkbox"/> Mina Mekhail mmekhail@uwo.ca	<input type="checkbox"/> Vikki Tran vikki.tran@uwo.ca
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This is an official document. Please retain the original in your files.

Western University, Research, Support Services Bldg., Rm. 5150
London, ON, Canada N6A 3K7 t. 519.661.3036 f. 519.850.2466 www.uwo.ca/research/services/ethics

Appendices

Appendix B: Professional Development Continuum Rubric

Professional Development Continuum Rubric

Element	Pre-Initiation Stage	Initiation Stage	Developing Stage	Sustaining Stage
Overall PLC Development	<input type="checkbox"/> The school has not yet begun to address a particular principle of a PLC.	<input type="checkbox"/> An effort has been made to address the principle, but the effort has not yet begun to impact a "critical mass."	<input type="checkbox"/> A critical mass has endorsed the principle. Members are beginning to modify their thinking and practice as they attempt to implement the principle. Structural changes are being made to align with the principle.	<input type="checkbox"/> The principle is deeply embedded in the school's culture. It represents a driving force in the daily work of the school. It is so internalized that it can survive changes in key personnel.
Mission Is it evident that learning for all is our core purpose?	<input type="checkbox"/> No effort has been made to engage faculty in identifying what they want students to learn, or how they will respond if students do not learn. School personnel view the mission of the school as teaching rather than learning.	<input type="checkbox"/> An attempt has been made, typically by the central office, to identify learning outcomes for all grade levels or courses, but this attempt has not impacted the practice of most teachers. Responding to students who are not learning is left to the discretion of individual teachers.	<input type="checkbox"/> Teachers are clear regarding the learning outcomes their students are to achieve. They have developed strategies to assess student mastery of these outcomes, they monitor the results, and they attempt to respond to students who are not learning.	<input type="checkbox"/> Learning outcomes are clearly articulated to all stakeholders in the school, and each student's attainment of the outcomes is carefully monitored. The school has developed systems to provide more time and support for students experiencing initial difficulty in achieving the outcomes. The practices, programs, and policies of the school are continually assessed on the basis of their impact on learning. Staff members work together to enhance their effectiveness in helping students achieve learning outcomes.
Shared Vision Do we know what we are trying to create?	<input type="checkbox"/> No effort has been made to engage faculty in describing preferred conditions for their school.	<input type="checkbox"/> A vision statement has been developed for the school, but most staff are unaware of, or are unaffected by it.	<input type="checkbox"/> Staff members have worked together to describe the school they are trying to create. They have endorsed this general description and feel a sense of ownership in it. School Improvement planning and staff development initiatives are tied to the shared vision.	<input type="checkbox"/> Staff members routinely articulate the major principles of the share vision and use those principles to guide their day-to-day efforts and decisions. They honestly assess the current reality in their school and continually seek effective strategies for reducing the discrepancies between the conditions described in the vision statement current reality.
Shared Values How must we behave to advance our vision?	<input type="checkbox"/> Staff members have not yet articulated the attitudes, behaviors, or commitments they are prepared to demonstrate to advance the mission of learning for all and the vision of what the school might become. If they discuss school improvement, they focus on what other groups must do.	<input type="checkbox"/> Staff members have articulated statements of beliefs or philosophy for their school; however, these value statements have not yet impacted their day-to-day work or the operation of the school.	<input type="checkbox"/> Staff members have made a conscious effort to articulate and promote the attitudes, behaviors, and commitments that will advance their vision of the school. Examples of the core values at work are shared in stories and celebrations. People are confronted when they behave in ways that are inconsistent with the core values.	<input type="checkbox"/> The values of the school are embedded in the school culture. These shared values are evident to new staff and to those outside of the school. They influence policies, procedures, and daily practices of the school as well as day-to-day decisions of individual staff members.
Goals What are our Priorities?	<input type="checkbox"/> No effort has been made to engage the staff in setting and defining school improvement goals related to student learning. If goals exist, they have been developed by the administration.	<input type="checkbox"/> Staff members have participated in a process to establish goals, but the goals are typically stated as projects to be accomplished, or are written so broadly that they are impossible to measure. The goals do not yet influence instructional decisions in a meaningful way.	<input type="checkbox"/> Staff members have worked together to establish long-and short-term improvement goals for their school. The goals are clearly communicated. Assessment tools and strategies have been developed and implemented to measure progress toward the goals.	<input type="checkbox"/> All staff pursue measurable performance goals as part of their routine responsibilities. Goals are clearly linked to the school's shared vision. Goal attainment is celebrated and staff members demonstrate willingness to identify and pursue challenging stretch goals.

Instructions: Please check the box for each row that best applies to the current situation happening in your school.

Element	Pre-Initiation Stage	Initiation Stage	Developing Stage	Sustaining Stage
Collaborative Culture: Teachers Working Together	Teachers work in isolation. There is little awareness of what or how colleagues are teaching.	Teachers recognize a common curriculum that they are responsible for teaching, but there is little exchange of ideas	Teachers function in work groups that meet periodically to complete certain tasks such as reviewing intended outcomes and coordinating calendars.	Teachers function as a team. They work collaboratively to identify collective goals, develop strategies to achieve those goals, gather relevant data, and learn from one another. Unlike a work group, they are characterized by common goals and interdependent efforts to achieve those goals.
Collaborative Culture: Administrator/Teacher Relations	Questions of power are a continuing source of controversy and friction. Relationships between teachers and administrators are often adversarial.	Efforts have been made to reduce friction by clarifying "management rights" and "teacher rights." Both parties are protective of intrusion onto their turf.	Administrators solicit and value teacher input as improvement initiatives are developed and considered, but administrators are regarded as having primary responsibility for school improvement.	Staff are fully involved in the decision-making processes of the school. Administrators pose questions, delegate authority, create collaborative decision-making processes, and provide staff with the information, training, and parameters they need to make good decisions. School improvement is viewed as a collective responsibility.
Parent Partnerships	There is little or no effort made to cultivate a partnership with parents. Parents are either ignored or viewed as adversaries.	An effort is made to keep parents informed of events and situations at school in order to secure parental support for the school's efforts.	Structures and processes for two-way communications with parents are developed. The parental perspective is solicited on both school wide issues and matters related directly to their own children.	The school-parent partnership moves beyond open communication. The school provides parents with information and materials that enable parents to assist their children in learning. Parents are welcomed in the school and there is an active volunteer program. Parents are full partners in the educational decisions that affect their children. Community resources are used to strengthen the school and student learning.
Action Research	While individual teachers may try experiments in their own classrooms, no structures to support, assess, or share their findings are in place. Many staff findings are in place. Many staff members have no knowledge of or involvement in action research.	Some staff members participate in pilot action projects. The sharing of findings is largely informal.	Staff members have been trained in action research methods and conduct action research to improve their professional practice. Findings generated by this research and beginning to influence classroom practices.	Topics for action research arise from the shared vision and goals of the school. Staff members regard action research as an important component of their professional responsibilities. There are frequent discussions regarding the implications of findings as teachers attempt to learn from the research of their colleagues
Continuous Improvement	Little attention is devoted to creating systems that enable either the school or individual teachers to track improvement. The school would have a difficult time answering the question, "Are we becoming more effective in achieving our shared vision?"	A few people in the school are tracking general indicators of achievement, such as mean scores on state and national tests. Positive trends are celebrated. Negative trends are dismissed or suppressed.	Individual teachers and teaching teams gather information that enables them to identify and monitor individual and team goals.	Everyone in the school participates in an ongoing cycle of systematic gathering and analysis of data to identify discrepancies between actual and desired results, goal setting to reduce the discrepancies, developing strategies to achieve the goals, and tracking improvement indicators.
Focus on Results	The results the school seeks for each student have not been identified.	Results have been identified, but are stated in such broad and esoteric terms that they are impossible to measure. Improvement initiatives focus on inputs-projects or tasks to be completed – rather than on student achievements.	Desired results have been identified in terms of student outcomes and student achievement indicators have been identified. Data are being collected and monitored within the school or district. Results of the analysis are shared with teachers.	Teams of teachers are hungry for information on results. They gather relevant data and use these data to identify improvement goals and to monitor progress toward goals.

Appendix C: Science Teaching Efficacy Belief Instrument-A

Science Teaching Efficacy Belief Instrument

Please indicate the degree to which you agree or disagree with each statement below by circling the appropriate letters to the right of each statement.

SA = Strongly Agree

A = Agree

UN = Uncertain

D = Disagree

SD = Strongly Disagree

- | | | |
|-----|---|--------------|
| 1. | I am continually finding better ways to teach science. | SA A UN D SD |
| 2. | Even when I try very hard, I don't teach science as well as I do most subjects. | SA A UN D SD |
| 3. | I know the steps necessary to teach science concepts effectively. | SA A UN D SD |
| 4. | I am not very effective in monitoring science experiments. | SA A UN D SD |
| 5. | I generally teach science ineffectively. | SA A UN D SD |
| 6. | I understand science concepts well enough to be effective in teaching elementary science. | SA A UN D SD |
| 7. | I find it difficult to explain to students why science experiments work. | SA A UN D SD |
| 8. | I am typically able to answer students' science questions. | SA A UN D SD |
| 9. | I wonder if I have the necessary skills to teach science. | SA A UN D SD |
| 10. | Given a choice, I would not invite the principal to evaluate my science teaching. | SA A UN D SD |
| 11. | When a student has difficulty understanding a science concept, I am usually at a loss as to how to help the student understand it better. | SA A UN D SD |
| 12. | When teaching science, I usually welcome student questions. | SA A UN D SD |
| 13. | I don't know what to do to turn students on to science. | SA A UN D SD |

*In Riggs, I., & Knoch, L. (1990). Towards the development of an elementary teacher's science teaching efficacy belief instrument. *Science Education*, 74, 625-637.

Appendix D: Science Teachers' Pedagogical Discontentment Scale

Science Teachers' Pedagogical Discontentment Survey

II. Specific Science Teaching Discontentment

Read each statement below and indicate your level of discontentment in terms of your own science teaching. In other words, how discontent are you currently with these aspects of your daily science teaching? Next to each item, circle one of the following choices:

- | | |
|----------------------------|-------------------------------|
| 1. No discontentment | 4. Significant discontentment |
| 2. Slight discontentment | 5. Very high discontentment |
| 3. Moderate discontentment | |

1. Teaching science to students of lower ability levels.	1	2	3	4	5
2. Balancing personal science teaching goals with those of state and national standards.	1	2	3	4	5
3. Monitoring student understanding through alternative forms of assessment.	1	2	3	4	5
4. Orchestrating a balance between the needs of both high and low ability-level students.	1	2	3	4	5
5. Preparing students to assume new roles as learners within inquiry-based learning.	1	2	3	4	5
6. Using inquiry-based teaching within all content areas.	1	2	3	4	5
7. Assessing students' understandings from inquiry-based learning.	1	2	3	4	5
8. Assessing students' nature of science understandings.	1	2	3	4	5
9. Including all ability levels during inquiry-based teaching and learning.	1	2	3	4	5
10. Teaching science to students from economically disadvantaged backgrounds.	1	2	3	4	5
11. Planning and using alternative methods of assessment.	1	2	3	4	5
12. Having sufficient science content knowledge to generate lessons.	1	2	3	4	5
13. Teaching science to students of higher ability levels.	1	2	3	4	5
14. Teaching science subject matter that is unfamiliar to me.	1	2	3	4	5
15. Integrating nature of science throughout the curriculum.	1	2	3	4	5
16. Having sufficient science content knowledge to facilitate classroom discussions.	1	2	3	4	5
17. Using assessment practices to modify science teaching.	1	2	3	4	5
18. Developing strategies to teach nature of science.	1	2	3	4	5
19. Ability to plan successful inquiry-based activities/learning.	1	2	3	4	5
20. Balancing personal science teaching goals with state/rational testing requirements.	1	2	3	4	5
21. Balancing the depth versus breadth of science content being taught.	1	2	3	4	5

Appendix E: The Beliefs about Reformed Science Teaching and Learning

The Beliefs about Reformed Science Teaching and Learning

How People Learn About Science

The statements below describe different viewpoints concerning the ways students learn about science. Based on your beliefs about how people learn, indicate if you agree or disagree with each of the statements below using the following scale:

SD: Strongly Disagree D: Disagree A: Agree SA: Strongly Agree

1. Students develop many ideas about how the world works before they ever study about science in school.	SD	D	A	SA
2. Students learn in a disorderly fashion; they create their own knowledge by modifying their existing ideas in an effort to make sense of new and past experiences.	SD	D	A	SA
3. People are either talented at science or they are not, therefore student achievement in science is a reflection of their natural abilities.	SD	D	A	SA
4. Students are more likely to understand a scientific concept if the teacher explains the concept in a way that is clear and easy to understand.	SD	D	A	SA
5. Frequently, students have difficulty learning scientific concepts in school because their ideas about how the world works are often resistant to change.	SD	D	A	SA
6. Learning science is an orderly process; students learn by gradually accumulating more information about a topic over time.	SD	D	A	SA
7. Students know very little about science before they learn it in school.	SD	D	A	SA
8. Students learn the most when they are able to test, discuss, and debate many possible answers during activities that involve social interaction.	SD	D	A	SA

Lesson Design and Implementation

The statements below describe different ways science lessons can be designed and taught in school. Based on your opinion of how science should be taught, indicate if you agree or disagree with each of the statements below using the following scale:

SD: Strongly Disagree D: Disagree A: Agree SA: Strongly Agree

9. During a lesson, students should explore and conduct their own experiments with hands-on materials before the teacher discusses any scientific concepts with them.	SD	D	A	SA
10. During a lesson, teachers should spend more time asking questions that trigger divergent ways of thinking than they do explaining the concept to students.	SD	D	A	SA
11. Whenever students conduct an experiment during a science lesson, the teacher should give step-by-step instructions for the students to follow in order to prevent confusion and to make sure students get the correct results.	SD	D	A	SA
12. Experiments should be included in lessons as a way to reinforce the scientific concepts students have already learned in class.	SD	D	A	SA
13. Lessons should be designed in a way that allows students to learn new concepts through inquiry instead of through a lecture, a reading, or a demonstration.	SD	D	A	SA
14. During a lesson, students need to be given opportunities to test, debate, and challenge ideas with their peers.	SD	D	A	SA
15. During a lesson, all of the students in the class should be encouraged to use the same approach for conducting an experiment or solving a problem.	SD	D	A	SA
16. Assessments in science classes should only be given after instruction is completed; that way, the teacher can determine if the students have learned the material covered in class.	SD	D	A	SA

Characteristics of Teachers and the Learning Environment

The statements below describe different characteristics of teachers and classroom learning environments. Based on your opinion of what a good science teacher is like and what a classroom should be like, indicate if you agree or disagree with each of the statements below using the following scale:

SD: Strongly Disagree D: Disagree A: Agree SA: Strongly Agree

17. Students should do most of the talking in science classrooms.	SD	D	A	SA
18. Students should work independently as much as possible so they do not learn to rely on other students to do their work for them.	SD	D	A	SA
19. In science classrooms, students should be encouraged to challenge ideas while maintaining a climate of respect for what others have to say.	SD	D	A	SA
20. Teachers should allow students to help determine the direction and the focus of a lesson.	SD	D	A	SA
21. Students should be willing to accept the scientific ideas and theories presented to them during science class without question.	SD	D	A	SA
22. An excellent science teacher is someone who is really good at explaining complicated concepts clearly and simply so that everyone understands.	SD	D	A	SA
23. The teacher should motivate students to finish their work as quickly as possible.	SD	D	A	SA
24. Science teachers should primarily act as a resource person, working to support and enhance student investigations rather than explaining how things work.	SD	D	A	SA

The Nature of the Science Curriculum

The following statements describe different things that students can learn about in science while in school. Based on your opinion of what students should learn about during their science classes, indicate if you agree or disagree with each of the statements below using the following scale:

SD: Strongly Disagree D: Disagree A: Agree SA: Strongly Agree

25. A good science curriculum should focus on only a few scientific concepts a year, but in great detail.	SD	D	A	SA
26. The science curriculum should focus on the basic facts and skills of science that students will need to know later.	SD	D	A	SA
27. Students should know that scientific knowledge is discovered using the scientific method.	SD	D	A	SA
28. The science curriculum should encourage students to learn and value alternative modes of investigation or problem solving.	SD	D	A	SA
29. In order to prepare students for future classes, college, or a career in science, the science curriculum should cover as many different topics as possible over the course of a school year.	SD	D	A	SA
30. The science curriculum should help students develop the reasoning skills and habits of mind necessary to do science.	SD	D	A	SA
31. Students should learn that all science is based on a single scientific method—a step-by-step procedure that begins with “define the problem” and ends with “reporting the results.”	SD	D	A	SA
32. A good science curriculum should focus on the history and nature of science and how science affects people and societies.	SD	D	A	SA

Appendix F: Professional Development Log

Column1	Column2	Column3	Column4	Column5	Column6	Column7	Column8	Column9	Column10										
1	PROFESSIONAL DEVELOPMENT LOG																		
2	Month:																		
3																			
4																			
5	ID Number:																		
6	Date(s) of Activity (M/D/Y)	Log Number (please number each log)	Activity Title/Content topic (e.g., plants, planets)	Activity Code	Other (i.e. does not suit an activity code in the previous column) OR anything you would like to add	Purpose of the Activity (e.g. Strengthen subject matter knowledge)	Other	Amount of Time Focused on the Activity	When did the PD happen?	Other	Who did you Collaborate with?	Other	Active Learning	Other	Coherence	Learning Outcome	Describe any Changes to your Instructional Repertoire	Describe why you may feel your teaching knowledge changed from this activity	Key Ideas/Thoughts/other notes
7																			
8																			
9																			
10																			
11																			
12																			
13																			
14																			
15																			
16																			
17																			
18																			
19																			
20																			
21																			
22																			
23																			

*If you select the "other" option, please provide detail in the following column

Activity Codes

Courses, conferences, seminars, workshops attended
 Training/studying for credential(s)
 Distance-education courses/modules you completed
 Presentations you gave, articles/books published, posters presented, courses taught
 Consulting with peers, informal rounds with colleagues, mentoring (mentor or mentee)
 Reading journals/texts, publications; reviewing videos/DVDs for specific learning goals
 Independent research or using other resources
 Professional contributions (committee work, peer reviews)
 Other

Purpose of the activity

Discussion for assessment
 Discussion for evaluation
 Discussion for lesson planning
 Other

Amount of time focused on the activity

10 minutes
 15 minutes
 20 minutes
 25 minutes
 30 minutes
 35 minutes
 40 minutes
 45 minutes
 50 minutes
 55 minutes
 1 hour
 1:15 hour
 1:30 hour
 1:30+ hours

When did the Professional Development happen?

Scheduled time
 Prep time
 Lunch break
 After school hours

Before school hours
Hallway chatting
Other

Who did you collaborate with?

Colleagues from the same grade
Colleagues from a different grades
Other

Active Learning

Observe lessons of teaching technique
Lead group discussions
Develop curricula or lesson plans, which other participants reviewed
Reviewed students work or score assessments
Develop assessments or tasks
Practice what you learned and received feedback
Received/provided coaching or mentoring in the classroom
Gave a lecture or presentation to colleagues
Other

Coherence

The activity is consistent with your department or grade level plan to improve teaching
The activity is consistent with your own goals for your professional development
Based explicitly on what you have learned in earlier professional development activities

Learning outcome

I changed or modified/plan to modify my practice based on this learning activity.
I pursued/will pursue additional information.
The findings of this activity reaffirmed or enhanced my knowledge, and no change to my practice is needed at this time.
Other

Appendix G: Sample of the Initial Data Reduction Process Document Summary Form

Name of Document: Focus Group 2

Date of Document: March, 2015

Participants involved in the Document: Anna, Elsa, Belle, Researcher

Location: Participant School

Page #	Keywords/Concepts	Comments: Relationship to Research Questions
1 FG.2	Background information to describe the case Paragraph 1-6	Related to the methodology section and describing the participants and the case
1 FG.2	CPL in school & Academic teams (depends on teaching partners teaching style/ curriculum/teacher availability)	Question 5: Collaboration in teachers' academic team depends on whether there are other teachers who teach science on that team. For the intermediates, Elsa and Belle are the only science teachers so they can only collaborate with each other about science. Both teachers collaborate more with other teachers who teach the same grade because they share the same students and teach more of the same classes like language and math.
2 FG.2	Timetable & Principal leadership & Collaboration Common preparation time Common science periods	Question 4: Principal scheduled the intermediate teachers to have common preparation time. Meaning, they are on prep at the exact same time. During this time, teachers can collaborate about science. The intermediate teachers don't plan their science collaboration, it happens when needed. During this common prep. Time, if they do collaborate with other teachers, it is usually about language or math with teachers who teach the same grade. Anna doesn't collaborate with others in science because they don't teach with the DRIVE model - As part of Principals leadership, he scheduled common prep time for teachers to have the opportunity to collaborate. Principal also scheduled the intermediate teachers to teach science at the same time so that they can co-teach. But teachers don't co-teach because of the different curriculum.
2 FG.2	Teachers' opinions of the goal of science education (Paragraph 29-32)	Question 2: - Anna: to develop students thinking skills and the ability to use skills in everyday life - Elsa: getting students to like science, particularly girls - Belle: Get students to enjoy learning science and to help the particular students with exceptionalities do more hands-on learning.
3	Teaching Science:	Question 5: Teachers are aware that the push in science is to

Curriculum Vitae

EDUCATION

Doctor of Philosophy in Educational Studies (2016)

Applied Psychology

Faculty of Education, Western University (London, Ontario)

Dissertation: *Learning about teaching science: Improving teachers' practice through collaborative professional learning*

Supervisory: Jacqueline Specht, Ph.D.

Master of Science (2011)

Child and Youth Health, Graduate Program in Health and Rehabilitation Sciences

Faculty of Health and Rehabilitation Sciences, Western University (London, Ontario)

Thesis: Predicting Children's Language Abilities

Supervisor: Lisa Archibald, Ph.D.

Honours, Bachelor of Science (2009)

Double major in medical science and physiology

Faculty of Science, Western University (London, Ontario)

CERTIFICATIONS FROM WESTERN UNIVERSITY

Instructional skills workshop online (2015)

Certificate in university teaching and learning (2014)

Teaching and mentoring program for graduate students (2014)

Advanced teaching program (2011)

Teaching assistant training program (2010)

Future professor workshops (10+ sessions) (2013-2015)

ACADEMIC HONOURS, AWARDS, AND BURSARIES (2012-2016)

Ontario Student Opportunity Trust Fund Bursary (2015)

Faculty of Education Graduate Student Internal Conference Grant (2015)

Jessica Jean Campbell Coulson Research Award (2014)

Canadian Research Centre on Inclusive Education Research Award (2014)

Ontario Student Opportunity Trust Fund Bursary (2013)

Faculty of Education Graduate Student Internal Conference Grant (2013)

Ontario Student Opportunity Trust Fund Bursary (2012)

RELATED WORK EXPERIENCE (2012-2016)

Academic Consultant (2015 – present)

BeMo Academic Research Inc.

Graduate Research Assistant (2015-2016)

Supervisor: Jacqueline Specht, Ph.D.
Western University (London, Ontario)

Writing Instructor (2014-2015)

Huron University College (London, Ontario)

Teaching Assistant: Educational Psychology and Special Education (2014-2015)

Faculty of Education, B.Ed./Dip.Ed. Program

Research Assistant: Writing Assignments Across the Undergraduate Curriculum (2014)

Lead researcher: Roger Graves, Ph.D.
University of Alberta (Calgary, Alberta)

Research Assistant: Canadian Research Centre on Inclusive Education (2012-2014)

Director: Jacqueline Specht, Ph.D.
Western University (London, Ontario)

PUBLICATIONS

Specht, J., McGhie-Richmond, D., Loreman, T., Aylward, L., Bennett, S. Gallagher, T., Katz, J., Lyons, W., Metsala, J., Mirinda, P., Thompson, S., Young, G., **Cloutier, S.E** (2015). Teaching in Inclusive Classrooms: Efficacy and Beliefs of Canadian Preservice Teachers, *International Journal of Inclusive Education*, DOI: 10.1080/13603116.2015.1059501

Guest Editorship

Cloutier, S.E., Iantosca, J., & MacCormack, J. (Eds.). Self-regulated learning. *CAEP Dialogic*, 3.

REFEREED CONFERENCE PRESENTATIONS (2012-2016)

Graves, R., Hyland, T., & **Cloutier, S.E.** (2015, May). *Writing Then and Now: Seven Years of Examining Writing Assignments Across the Curriculum at a small Liberal Arts College*. Canadian Writing Centres Conference, University of Ottawa, Ottawa, Ontario, Canada.

Cloutier, S.E. & Hyland, T. (2015, May). Group work with International and Exchange Students in the Writing Centre. Canadian Writing Centre Conference, University of Ottawa, Ottawa, Ontario, Canada.

Cloutier, S.E. & Specht, J. (2015, May). New Professional Development Log Tracking the Effectiveness of Elementary Science Teachers Participation in Collaborative Professional Development Activities. Canadian Society for the Study of Education, University of Ottawa, Ottawa, Ontario, Canada.

Cloutier, S.E. & Specht, J. (2013, November). 21st Century Teaching and Learning in Ontario. Ontario Council for Exceptional Children, Niagara Falls, Canada.

Cloutier, S.E. & Specht, J. (2013, June). Effective teacher collaboration for inclusive practices. Canadian Society for the Study of Education, University of Victoria, Victoria, British Columbia, Canada.

McGhie-Richmond, D., Specht, J., Loreman, T., Aylward, L. Bennett, S., Gallagher, T., Katz, J., Lyons, W., Metsala, J., Mirenda, P., Thompson, S., Young, G., Copfer, S., Gregory, K., & **Cloutier, S.E.** (2013, June). New teachers' self-efficacy for teaching in diverse and inclusive classrooms: A Canadian snapshot. Canadian Society for the Study of Education, University of Victoria, Victoria, British Columbia, Canada.

ACADEMIC SERVICE AND LEADERSHIP (2012-2016)

Secretary: Canadian Writing Centre Association (2015-2016)

Coordinator of Graduate Student Representative Team: Canadian Association for Educational Psychology/L'association Canadienne en Psychopedagogie (2015-2016)

Graduate Student Representative: Canadian Association for Educational Psychology/L'association Canadienne en Psychopedagogie (2014-2015)

Junior Copy Editor and Reviewer: Canadian Journal for New Scholars in Education/Revue Canadienne Des jeunes chercheur(s) en education (2014-2015)

Ph.D. Mentor: Faculty of Education, Western University (2013-2014)

Facilitator of Doctoral Seminar Series: Faculty of Education, Western University (2013-2014)

Session Chair: 2015 Canadian Writing Centre Association Conference

Session Chair: 2015 Canadian Association for Educational Psychology

Peer Reviewer: 2015 Canadian Society for the Study of Education Conference

Discussant: 5th Annual Robert Macmillan Graduate Research in Education Symposium

Peer Reviewer: 2013 Canadian Society for the Study of Education Conference