IDENTIFYING THE CHALLANGES OF TEACHING INQUIRY-BASED SCIENCE IN NEW BRUNSWICK ELEMENTARY SCHOOLS

by

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ABSTRACT

This study aimed to uncover the challenges New Brunswick elementary school teachers face when trying to implement inquiry-based science in their classrooms. Inquiry-based instruction has been used to improve student attitudes and understanding of the scientific process (Flick & Lederman, 2006; Gess-Newsome, 2002; Lederman, 1999). The Conference Board of Canada (2014) suggests students in New Brunswick trail the rest of Canadian students in science related testing (Conference Board of Canada, 2014). New Brunswick teachers were surveyed and then asked to complete in depth interviews to discuss their experiences with science education. The findings of this research suggest that surface level challenges such as lack of resources, time and education contribute to inadequate science instruction. Alternative perceptions of science and inquiry, and a lack of agency to improvement methods embodied a deeper set of challenges that participants were not always consciously aware of. Many recommendations have been presented to promote the use of using inquiry-based science instruction by elementary teachers in New Brunswick.

DEDICATION

This study is dedicated to my former supervisor and mentor, Dr. Ann Sherman. Dr. Ann Sherman propelled me into the world of science education and inquiry-based learning. She always trusted me to take chances and explore my potential. I will remember Ann from the memories of this project and all future science education endeavours I encounter.

I thank my family, friends and colleagues for being patient with me through the process of doing research.

Finally, I thank my current supervisor Mark Hirschkorn for getting back on track during a challenging time and navigating me through this document.

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CHAPTER 1

"Obviously I do things everyday that involve it [science], but when I think of education I'm thinking I'm supposed to be teaching these children something about how water can be a solid and a liquid. You know what I mean? That's the way I think of science".

Participant Sam (research interview)

Introduction

Research Context

I worked for four years developing science kits to implement inquiry-based teaching in classrooms around New Brunswick, Canada. This study is an extension of this work and explores a research question intended to provide a better understanding of how elementary teachers approach teaching and learning science in the province of New Brunswick. Research data informed a set of recommendations to promote and support elementary level teachers teaching inquiry-based science.

In 2008, I was introduced to the practices of designing hands-on and inquiry-based science experiments and activities through science outreach programs and science focused summer camps. I was able to observe the effectiveness of both hands-on and inquiry-based learning and how students were able to form cognitive connections while developing scientific concepts and ideas. I began to subscribe to the 5E development model of instruction with a balance of demonstrational, inquiry driven and explanatory activities based in a variety of scientific disciplines (Bybee, Taylor, Gardner, Van Scotter, Powell, Westbrook & Landes, 2006).

Four years later I began studying for my undergraduate degree in education at UNB. Through a shared interest of inquiry-based science instruction I was introduced to the Dean of Education at UNB, Dr. Ann Sherman. Dr. Sherman hired me to improve an existing set of science resource kits and create more of these kits to assist teachers with their science instruction.

While creating the science kits, I worked to construct lesson plans and resource materials for several elementary grade levels. I have subsequently implemented these kits in classrooms around New Brunswick to support the needs of teachers while promoting the use of inquiry-based pedagogies. During my time working with teachers I observed alternative perceptions about teaching inquiry-based science. Some teachers expressed discomfort teaching science and described how some students were unhappy with the lack of science classes they experienced. This study allowed me to provide an inquiry-based professional learning workshop to improve teachers' understanding, and attitudes towards science while collecting data to reveal the challenges elementary teachers experience teaching science in New Brunswick.

Key Terms

Western science. This study was framed through the western science perspective. The New Brunswick science curriculum does not identify non-western science methodologies. Therefore, I am referring to science in the western perspective.

There are many other science methodologies and perspectives in Canada, including various forms of Traditional Knowledge (Aikenhead, 1997), which New Brunswick science curriculums do not identify.

According to Mazzocchi (2006), "western science favors analytical and reductionist methods" (p. 463) with an objective and quantitative framework. Though there are criticisms of western science and the exclusion of a more holistic scientific approach, New Brunswick has yet to adapt to the Traditional Knowledge methods that provinces such as Manitoba have implemented successfully (Kanu, 2011).

Alternative perceptions. In this study, alternative perceptions are defined as inaccurate understandings of scientific principles according to the western science framework while recognizing and remaining sensitive to personal beliefs, backgrounds and positions. This definition was modelled after the term alternative conceptions which relate more to inaccuracies regarding scientific content (Gilbert & Watts, 1983; Driver & Easley, 1978).

Purpose of this research

With declining national score results in science (Conference Board of Canada, 2014), New Brunswick teachers are encouraged to find innovative ways to increase student engagement and success in their scientific studies. Provincial enrolment numbers in science and technology post-secondary programs within New Brunswick have declined in recent years, and New Brunswick students have consistently scored amongst the lowest in the country on standardized tests in science (Conference Board of Canada, 2014; NBDEECD, 2002). This problem needs to be addressed with plausible and affordable solutions.

Teaching science through inquiry-based pedagogy has been shown to enhance student content knowledge and improve student attitudes toward science (Flick & Lederman, 2006; Gess-Newsome, 2002; Lederman, 1999). Inquiry-based learning is not a new teaching strategy though it may not always be properly understood by primary school teachers (Kuhn & Dean Jr., 2005; Lederman & Abell, 2014; Levitt, 2002). This research aimed to identify the specific challenges of facilitating inquiry-based learning in New Brunswick science classrooms while recommending methods of successful implementation for future consideration.

Research Question

My research question asks,

<u>What challenges do elementary school teachers encounter when implementing inquiry-based instruction while teaching science in New Brunswick schools?</u>

CHAPTER 2

"it [inquiry] is actually really fun once you start doing the hands-on approach, and then you actually feel like you don't need to know as much because you can pretend you're just discovering with the kids."

Participant Ashley (research interview)

Literature Review

Many primary school teachers struggle to instruct science through an inquiry-based pedagogy (Luft, Bell & Gess-Newsome, 2008). Background, personal beliefs, content knowledge and culture are all factors shaping an individual's teaching philosophy in the classroom (Friedrichsen et al., 2011). Often, elementary school teachers lack a strong scientific background (Appleton, 2003) and, therefore, may have alternative perceptions of how science is practiced (Abd-El-Khalick, 2001). Professional development in science teaching receives much less promotion than those based on literacy and numeracy, however scientific inquiry has been identified as a major tool for students as they develop critical thinking skills and ability to understand the world around them (Flick & Lederman, 2006). The systemic emphasis on literacy and math instruction has also enabled teachers to place the science curriculum at the "edges of the instructional program" (Sandholtz & Ringstaff, 2014, p. 746).

This review of the literature has been arranged to first identify challenges elementary school science teachers face, then to explore some possible reasons why teachers are unwilling to use inquiry-based science, and finally to investigate what solutions are out there (figure 1). The diagram in figure 1 depicts the flow of this literature review and the progression from challenges to possible solutions in the existing literature.

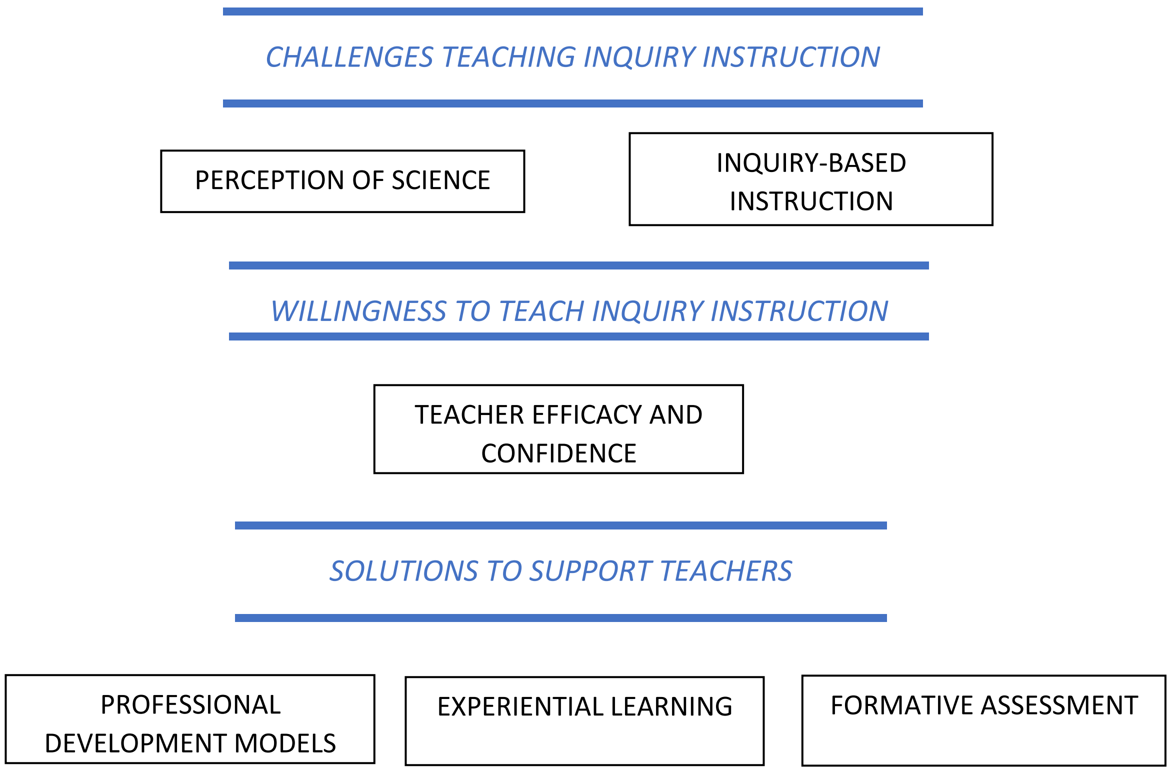

Figure 1: Flow diagram of the literature review progression.

Challenges Teaching with Inquiry

Scientific-inquiry has become a staple in most modern curriculum expectations (Lederman & Abell, 2014; NRC, 2012; NRC, 2013; NBDEECD, 2002). However, to teach inquiry-based lessons one must have the fundamental understanding that science is a tool which we use to better understand the world around us.

Perceptions of science. Scientific thinking can be interpreted differently based on society's interactions and relationships with the scientific community (Schulz, 2014). Though there are many philosophical ideas about the purpose of science, in order to properly inform our understanding of 'what is science?', elements of knowledge acquisition and the systematic methodology of obtaining this knowledge must be considered (Schulz, 2014). In other words, the 'what' and 'how' of doing science are critical to understanding the mechanics of thinking scientifically.

Schulz (2014) states "it is clear that changes in one field takes decades before it impacts the other" (p. 33) indicating that changes in the philosophy of science education may lag behind the evolving views and current trends in the scientific community. For decades, scientists have struggled to eliminate the general population's belief that science operates on single "truths" with a positivist epistemology (Schulz, 2014). Osborne, Simon, and Collins (2003) argue that declining numbers of enrollments into post-secondary science programs can be directly linked to students' and teachers' alternative conceptions of science and scientific professionals.

According to Statistics Canada, 84% of elementary school teachers in Canada are female (Stats Can, 2007). Farengna and Joyce (1999), identified a variety of factors that shape a student's perception of science. According to their research, "Certain subjects are perceived as masculine or feminine by elementary school students" (p. 61) and "they [students] perceive scientists as predominantly male" (Farenga & Joyce, 1999, p. 61). These perceptions support a negative gender barrier for female students and a preconception of who should be involved in scientific studies and research. In this light, female elementary teachers are vulnerable to feeling disconnected to scientific subject matter.

Cultural beliefs of western society may also shape assumptions and stereotypes regarding gender roles in science. Stereotypes may act as “cognitive crutches in situations in which we do not know how to judge our performance” (Hill et al., 2010, p. 45). Moss-Racusin, Dovidio, Brescoll, Graham & Handelsman, (2012) established evidence that even individuals in support of gender equity still harbor implicit biases and stereotypes about females in the STEM industries. Their study involved male and female STEM faculty participants from many high-ranking colleges in the US. The participants rated male applicants, “significantly more competent and hireable than the (identical) female applicant” (Moss-Racusin, Dovidio, Brescoll, Graham & Handelsman, 2012, p. 16474). Faculty participants also selected a higher starting salary and offered more career mentoring to the male applicant while both male and female participants exhibited bias towards applicants equally. This research, amongst other similar findings (Gokhale, Rabe-Hemp, Woeste & Machina, 2014), indicates the possibility of unconsciously practicing discriminatory judgments without personally endorsing gender-based stereotyping in the STEM field.

Teachers convey their personal ideologies of scientific instruction and exploration through their own life experiences (Lederman & Abell, 2014). Unfortunately, many practicing and preservice teachers with weak scientific backgrounds define science inaccurately as a ‘product-based’ practice rather than a ‘process-based’ exploration (Gess-Newsome, 2002; Lederman & Abell, 2014).

Alternative perceptions of science may translate to teachers constricting science lessons around reading textbooks and having students generate answers to questions. This didactic approach used by teachers unintentionally presents the scientific method in a way in which memory and trivial knowledge become the focal point to learning concepts (Gess-Newsome & Lederman, 1999). In these cases, teachers leave students accountable for their answers and knowledge outcomes without enough support (Friedrichsen et al., 2011). A more realistic introduction to learning science enables students to generate questions while teachers facilitates some possible routes of discovery in which students are able to seek possible solutions to the questions (Brand & Moore, 2011).

Learning with scientific inquiry. Science can be, and has been, instructed with a variety of pedagogical approaches. Trends in western science education continue to change as the focus of society shifts. Many modern researchers and educational associations today agree that inquiry-based science should be a foundational platform throughout the elementary school science curriculum (NRC, 2012; NRC, 2013; NBDEECD, 2002).

Scientific inquiry represents not only how scientists practice, but also how students most effectively learn science (Sheninger & Devereaux, 2013). According to Kuhn and Dean Jr. (2005), “Inquiry is a complex, multifaceted activity” (p. 867). Students must learn to create a cognitive concept of science actively (Gess-Newsome, 2002) in order to scaffold a basic understanding of what it means to ‘do’ science (Davis & Smithey, 2009). Sheninger and Devereaux (2013) describe the need for students who are learning science to be “making observations, asking questions, exploring natural phenomena, conducting experiments, finding patterns in data, seeking knowledge, and solving problems” (p. 7). The burden of facilitating these specialty skills to a group of students can be intimidating for a teacher who may be intimidated by the content knowledge within the science curriculum (Appleton, 2003). This concept of teaching through inquiry may contradict traditional approaches to instructing science that current teachers learned during their time in school (Levitt, 2002).

A lack of sufficient coursework and experience with scientific material can leave elementary school teachers unprepared to engage students in practices of inquiry (Davis & Smithey, 2009). Inquiry-based science has become a “prerequisite to any hope of achieving a vision of science teaching and learning” (Flick & Lederman, 2006, p 303). This becomes a major issue if the teachers themselves have alternative perceptions regarding how to ‘do’ inquiry activities (Luft et al., 2008). This misunderstanding has been repeatedly uncovered during research conducted with preservice teachers (Forbes, 2011; Abd-El-Khalick, 2001; Sherman & MacDonald, 2007; Gess-Newsome, 2002).

Some teachers claim to feel comfortable teaching inquiry-based science through a more open form of inquiry without guiding students through the process of learning (Kuhn & Dean Jr., 2005). These teachers believe that inquiry-based learning requires the students to develop their own questions and to try to solve them using an open-ended plan. More often than not during these lessons students ask too many questions and flood an idea with variables (Kuhn & Dean Jr., 2005) leading to ineffective plans and testing methods to answer these questions. This style of teaching is not always effective because teachers are no longer responsible for the learning taking place (Kuhn & Dean Jr., 2005).

Many teachers require professional growth opportunities to effectively understand how to facilitate inquiry-based learning and direct students on a pathway which promotes practicing good science. Students need exposure to inquiry-based science in hopes of developing a strong scientific literacy (Duran & Duran, 2004.). Similarly, before students acquire language arts skills, "children need to know how to hold a book, which direction to turn the pages, the letters of the alphabet and the sounds each makes, and the general components of stories" (Davis & Smithey, 2009, p. 760). One successful model that identifies components needed to build inquiry-based learning has been identified as the 5E instructional model (Duran & Duran, 2004).

The 5E instruction model was developed in the 1980's by the Biological Sciences Curriculum Study (BSCS) to improve the current methods of teaching science (Bybee et al., 2006). The five phases of this model include, engagement, exploration, explanation, elaboration and evaluation. The engagement phase requires students to draw upon past learning experiences while exposing alternative conceptions in order to leave students puzzled yet motivated to discover (Bybee et al., 2006). Exploration "initiates the process of equilibrium" (Byebee et al., 2006, p .10) by allowing students to work towards formulating experiences which teachers may draw upon later to explain scientific concepts. The teacher must act as a facilitator during this phase.

The explanation phase acts to make sense of these active processes and according to the BSCS, “The key to this phase is to present concepts, processes, or skills briefly, simply, clearly, and directly” (Bybee et al., 2006, p. 9) before entering the next phase of the 5E model. Ideally, students will take their new sense of knowledge and expand their understanding in the elaboration phase. Discussions and information seeking activities are crucial to this concept development phase (Bybee et al., 2006). Finally, teachers will initiate the formal evaluation and assessment process targeting educational outcomes to determine each student’s level of understanding generated throughout the 5E cycle. This model of instruction gracefully facilitates and directs the inquiry-based learning approach to science lessons (Duran & Duran, 2004).

The current New Brunswick Department of Education and Early Childhood Development (NBDEECD), Atlantic Canada Science curriculum states that, “Scientific inquiry, problem-solving and decision making support students to become life-long learners and to maintain a sense of wonder about the world around them.” (NBDEECD, 2002, p. 1). By requesting individuals to facilitate such inquiry-based activities without preparing them for how inquiry is practiced, teachers are likely to continue the more traditional teaching strategy of transmitting knowledge and skills to students, often inaccurately.

Teacher Willingness, Efficacy and Content Confidence

Many factors influence the decisions teachers make in planning science units and lessons at the elementary level. The decisions could be motivated by confidence level, comprehension of content and the past experiences in a science classroom. This section will examine the autonomy given to elementary teachers and some possibilities to understand the question, "are elementary school teachers willing to use inquiry-based science"?

Self-efficacy can be defined as "a judgment of one's own capabilities to perform actions that they believe could lead to desired results" (Menon & Sadler, 2016, p 650). In relation to teaching, self-efficacy plays an important role in understanding the confidence teachers must maintain to instruct curriculum materials effectively. Teachers may feel powerless if they believe teaching strategies used in their classrooms are ineffective or if content knowledge is unclear.

A self-efficacy construct was developed by Bandura (1977) to demonstrate how teachers' instructional performances may lead to desired outcomes required by the curriculum that is based on teachers' own perceptions of their teaching pedagogies. Teachers may lose motivation and avoid teaching science content if they possess a poor self-efficacy (Posnanski, 2002). It is no surprise that with these challenges through science instruction and self-efficacy, many teachers avoid instructing these disciplines (Appleton & Kindt, 2002) while sticking to subjects that are more manageable and easier to understand, or to teaching strategies that would be at best described as didactic in approach.

Though confidence issues are evident in teachers at any level of experience, educators who are early on in their career are more vulnerable to self-efficacy struggles (Appleton, 2003; Menon & Sadler, 2016). Beginning teachers are working to develop their own pedagogical practices and tend to focus on their own performance rather than the performance of students (Davis & Smithey, 2009). Sherman and MacDonald (2007) identify content knowledge as a common discomfort area for preservice teachers. These early professionals expressed having a fear of explaining scientific concepts to their students (Sherman & MacDonald, 2007).

Menon and Sadler (2016) reported that preservice teachers, both those with and without science content backgrounds, were found to have negative attitudes and beliefs about the teaching of science. In some cases, undergraduate science courses have resulted in a negative outlook towards the teaching of science materials (Plourde, 2002). In addition, sufficient content knowledge in the sciences does not always directly result in effective science teaching strategies (Posnanski, 2002).

Subject material can also impact the confidence level of science teachers. Sandholtz and Ringstaff (2014) noted that during their education careers, “they [teachers] are unable to see the connection between the content of their undergraduate science courses and the content they will be teaching to elementary-aged students” (p. 730). Elementary teachers reported greater comfort levels teaching life and earth sciences in comparison to physics and/or chemistry (Banilower, Smith, Weiss, Malzahn, Campbell & Weis, 2013). This may be linked to a higher rate of enrollment in biology undergraduate courses for prospective teachers over physics, chemistry, etc. (Sandholtz & Ringstaff, 2014).

The literature on teacher confidence and efficacy directly relates to my experiences working in local elementary schools. Teachers have openly expressed their dissatisfaction with trying to teach inquiry-based science. Many of these teachers expressed a great interest in learning more about how scientific inquiry works in a classroom environment. Among the variety of challenges elementary science teachers face, I believe that improving teacher confidence with inquiry-based learning would significantly improve the classroom experience of elementary level students.

Possible Solutions

In this section I will present a brief array of viable tools that were described in the literature to help elementary school teachers use inquiry in their science classrooms. These tools act as a comparative starting point for the data derived during this study. Some of these solutions include professional development models and practice with experiential learning while others focus on the way teachers conduct assessment in science class.

Experiential learning theory. Inquiry-based learning in schools has been promoted by educational philosophers for over a century. Dewey (1938) introduced the idea of inquiry as part of the basic process of how we think, understand and learn. He described the importance of establishing a discipline of education for “experiential learning” in which the individual learns by taking action and reflecting on their own experiences (Dewey, 1938). The active participation of the learner develops meaning and deeper understanding leading to informed decision making and problem solving (Brand & Moore, 2011).

Based on the work of Dewey, Vygotsky and others, Kolb, Kolb, Passarelli, & Sharma (2014) studied the benefits of learning through experiences and reflection. Experiential education can be defined as a process in which the teacher and learner engage in a multifaceted and complex process that balances deep understanding, self-reflection and the ability to apply these skills to a task (Kolb et al., 2014). This method of building conceptual ideas can be directly packaged with the pedagogical approaches used to deliver effective inquiry-based science lessons.

Gilbert et al. (2014) have suggested that active learning in undergraduate courses could be linked to improved learning outcomes. The study operated on a year-long internship project in which life science students were challenged to increase their knowledge acquisition and build on practical skill applications during an internship program. These students felt better informed to make decision upon entering the work force (Gilbert, Banks, Houser, Rhodes & Dourgals Lees, 2014). The real-life situations in the scientific work force required a higher order of thinking which is effectively simulated in the experiential education model (Gilbert et al., 2014).

Professional growth models. Many elementary school teachers across North America seem to have become complacent with traditional science instruction, preferring not to teach science through an inquiry approach and instead using the 'textbook' route of instruction (Appleton & Kindt, 2002; Appleton, 2003). This phenomenon exposes the "need to investigate strategies for promoting teachers' orientation to practices in alignment with the recommendations of science education reform" (Brand & Moore, 2011: p 908). Posnanski (2002) believes that science teachers need “continuous skill development throughout their careers” (p 189) in order to be most effective as educators. Content knowledge in science has been identified as an area in which elementary teachers wish to participate in through increased professional development opportunities (Fulp, 2002). Current trends in the professional development of teachers include developing the skills of inquiry-based learning, student-teacher-scientist relationships, experiential learning and exploring science through a culturally diverse curriculum (Gess-Newsome, 2002; Fallon, 2013; Kolb et al., 2014; Duran & Duran, 2004; Van Driel, 2001; Settlage & Southerland, 2014; Brand & Moore, 2011).

Many times, professional development models fail due to “unused curriculum notebooks and teachers’ accounts of the lack of time and opportunity to effectively process and use the ideas” (Brand & Moore, 2011: p 909). Van Driel et al (2001) stated that “When implementing a new curriculum, teachers appeared to adapt this curriculum according to their own context and beliefs” (p 146). Adding an inquiry science kit to the curriculum can cause teachers great frustration due to time constraints and lack of pedagogical preparation (Jones & Eick, 2007). Teachers often adapt these kits in ways that emphasize their own teaching style and pedagogical strengths (Jones & Eick, 2007).

The constructivist-sociocultural model introduced to elementary school teachers by Brand and Moore (2011) “encouraged teachers’ critical analysis of their instructional practices to include identifying and understanding factors influencing their choice of strategies.” (p 900). The project aimed to alter the perceptions and practices of teachers using inquiry-based scientific workshop activities. Posnanski (2002) believes a teacher's ability to be reflective in the learning process results in the reconstruction of knowledge and teaching practices. Peer coaching is another effective approach to skill development and knowledge acquisition for inexperienced science teachers. Peer coaching can be seen as a process of cooperation between two or more colleagues in which they exchange ideas (Van Driel et al., 2001). Peer coaching works well when the interactions are on an equal basis.

Bergman and Morphew (2015) and Menon and Sadler (2016) found that the level of science content knowledge (SCK) directly impacts the teaching efficacy of elementary school teachers. By offering preservice teachers a class based on elementary physics content teachers increased their efficacy and confidence level beginning their teaching careers (Menon & Sandler, 2016). Sandholtz and Ringstaff (2014) found teachers with one year of science education professional development support switched from a teacher-centered to a student-centered method of instruction. The professional growth program was prepared by professionals who were able to directly address specific needs and requirements of the teachers. Other research confirms that teachers must be involved in reform to maximize successful transmission of new practices (Van Driel et al., 2001). Posnanski's (2002) research adds that "contemporary views of staff development promote a constructivist approach in the delivery of professional developments programs" (Posnanski, 2002, p 190) which allows teachers to step back and analyze their teaching style in order to choose their preferred method of delivery.

Over the past decade, a new science instructional strategy has been adopted by some schools. The Teacher-Scientist partnership model (TSPM) offers students an opportunity to practice real science with real scientists (Houseal, Abd-El-Khalick & Destefano, 2014). These teams engage in mutually beneficial science based activities (Falloon, 2013). Though these models can be traced back to the 1980's, only recently have they been analyzed and developed to promote an increase in science teacher efficacy. These partnerships require input from all involved to promote shared responsibilities in developing the education of the students (Falloon, 2013).

The benefits of the TSPM are evident in the unique experiences offered for students to acquire a genuine perception of how science is practiced in the real world (Houseal et al., 2014). Inquiry-based science in the classroom may be limited in the way students are able to understand who practices science and how they practice it. The scientists also prosper by collecting large amounts of data that would otherwise take much longer. Houseal et al., (2014) found a correlation between the TSPM and how teachers value scientific curriculum outcomes and content knowledge. Similarly, Peker and Dolan (2012) observed results in which the teacher-scientist partnerships proved to be mutually beneficial due to sharing responsibility of student learning.

Falloon (2013) presents some problematic variables that can mean that the teacher-scientist partnership can be "extremely difficult to achieve" (p 858). Faloon's study matched New Zealand public schools with an industrial forestry company with a variety of scientists participating. The results were concerning as the teachers were not included in the design of the curriculum and, as a result, felt like outsiders to the project. During the interview process, teachers expressed that they would prefer to increase their confidence level with science materials, but this project did not address these issues. The scientists seemed worried that “tension existed [within their] sense of responsibility to schools” (Falloon, 2013: p 867) and suggested that teachers and students seemed to have become dependent on their presence for effective long-term learning.

Assessment strategies in science education. High stakes testing (HST) results have increased the validity and importance of elementary science content (Madden & Wiebe, 2013). Though formative assessment has an important role in the classroom, HST still plays a major role when analyzing school performance. Accurate assessment results in science are used on a state and provincial level to clarify future goals for science education (Wilson, 2006). Education operates through complex levels including classroom, school, district, state/province, and national regulations. Systematically formed HST’s must exist within a well-connected feedback loop which respects the state and provincial differences which determine their unique curricular decisions. The allocation of resources in these curricula must promote opportunity to each student in the context of their learning environment and this is not always the same on a national level.

The traditional process of collecting data has been through multiple choice tests. Scantron answer sheets are time efficient and eliminate any opportunity for teacher influence or bias through marking. This style of testing requires memorization, recall and often leads to teachers moving away from the inquiry-based instruction that students require to construct strong scientific thinking patterns. Suppovitz (2009) argues that successful HST's require short, medium, and long-cycle assessments in connected matrix of student achievements.

The recently expanding value and implementation of formative assessment has brought focus back to each students' thinking process rather than content knowledge. Bell and Cowie (2000) suggest that "Each learner has to construct an understanding for her or himself, using both incoming stimuli and existing knowledge" (Bell & Cowie, 2000; p5). This process is highly contextualized and gives students the opportunity to learn about how they truly relate to science and learning science.

Formative assessment requires a heavier workload and practicing formative assessment leaves teachers in vulnerable position with elements of "uncertainty and risk taking" (Bell & Cowie, 2000, p35). Teachers lacking in confidence with science materials may not be comfortable taking risks with formative assessment to support their students' constructions of scientific concepts. As mentioned earlier, many teachers misunderstand the purpose of science and convey a project this perception towards their students. However, students develop their scientific thinking based on perceptions of what science is, who uses science and how science can be used as a tool (Bell & Cowie, 2000).

Cauley & McMillan (2010) stress the succession of formative assessment strategies to illuminate the importance of communication between students and teachers. Scientific learning is constructed though content, context and process, and formative assessment strategies best support these three elements of development. Teachers implementing formative assessment into day-to-day instruction produce information which they can use to modify their instruction and support an active source of self-assessment from their students. Motivation and achievement levels increase through practicing effective formative assessment in schools (Cauley & McMillan, 2010).

One of the many methods of formative assessment in science classrooms is through scientific notebooks. Each teachers' instructional practices are influenced by their unique teacher identities and these practices translate to the implementation of formative assessment tools (such as notebooks) resulting in their students' participation with scientific materials (Wiebe, Madden, Bedward, Minogue & Carter, 2009). Wiebe et al (2009) found that science notebooks used over extended periods of time are extremely effective in capturing daily activity from the students' perspectives and adding a missing source of knowledge to support the formative assessment process. Meanwhile, tests only reflect the learning process over a shorter period of time.

Summary of the Literature

The challenges of teaching elementary sciences have been documented through various research and this information acts as a point of comparison for this study. Challenges include understanding inquiry-based instruction, self-efficacy with science content knowledge, and the ineffective strategies of professional development. I explored phenomena experienced by other teachers across Canada and worldwide to contextualize the challenges of elementary science teachers in New Brunswick. This thesis identifies the challenges New Brunswick teachers are facing and provides realistic suggestions to improve their inquiry-based approaches.

CHAPTER 3

“Even in expecting, one leaps away from the possible and gets a footing in the real.
It is for its reality that what is expected is expected”

Heidegger (Being and Time, 1962)

Methodology

This study used a constructivist approach integrated with phenomenological research. The following section describes phenomenological research and why I decided to frame this research project with this design. I am concluding this chapter with explanations of specifically how I brought this methodology to life in this study.

Phenomenology

“Phenomenology is the study of structures of consciousness as experienced from the first-person point of view” (Smith, 2008) and has often been used in sociology, psychology, life sciences and education research (Creswell, 2007). Phenomenological research was designed to answer questions about thinking and learning while addressing the relationships that people have with the world around them. This design requires researchers to orient themselves toward participants’ experiences of a certain phenomenon (Creswell, 2013).

The roots of phenomenological research lie in the work of philosopher Edmund Husserl (1859-1938) who strived to study consciousness (Husserl, 1991). He believed that our state of consciousness is shaped by intersubjectivity of all that came before us, which makes it impossible to gain a state of presupposition on any given phenomenon (Husserl, 1970). Husserl described phenomenology as a state of being or way of seeing rather than a set structure of procedural regulations. Using this "lens of consciousness" or intuitive seeing, phenomenological research can uncover natural meanings and explanations (Gallagher, 2012). The goal in a phenomenological study is to give better understanding to guileless interactions with the world around us (Merleau-Ponty, 1962).

Philosophers such as Heidegger (1889-1976) and Merleau-Ponty (1908-1961) would continue to develop the philosophy of phenomenology into two branches, hermeneutic and transcendental. Heidegger, a student of Husserl, believed that individuals understanding of their own situated place in the world would shape their relation to reality (Heidegger, 1962). Preunderstanding (Heidegger, 1962) relates to how an individual cannot escape an existing cultural position that is in place before the existence of the individual. With this theoretical frame, hermeneutic phenomenology is an inclusive process with room for interpretation and welcomes the lived experiences of the researcher to inform the study. On this basis, I have adopted hermeneutic phenomenology as a research methodology. My research question can be related to hermeneutic phenomenology through philosophical choices and attitude.

Research Question:

<u>What challenges do elementary school teachers encounter when implementing inquiry-based instruction while teaching science in New Brunswick schools?</u>

I approached my research question with a desire to collect a variety of teacher experiences with inquiry-based science instruction, including my own. Based on my support of the socio-construct model (Brand & Moore, 2011), I adopted the views of Husserl's (1970) phenomenology as a methodological framework in which participants develop self-awareness of how their beliefs connect to their existence (Husserl, 1970). This research project concentrated predominantly on teacher experiences and perspective.

Criticisms and Limitations of Phenomenology

Though seeking a richer perspective from a group of teachers experiencing the same phenomenon can be very valuable, as with any frame of study, the phenomenological approach has been met with many critiques. Though most critiques come from the philosophical nature of the term, phenomenology as a research methodology has also been in question.

One of the strongest critiques of phenomenology would be toward the 'bracketing' process. Bracketing involves setting aside the question of existence and the nature of reality (Husserl, 1991). Some of the methods recommended for phenomenological data collection (i.e. one-on-one interviews) require the researcher to escape or 'bracket' (Creswell, 2007) their subjective experiences and the empirical world which can be extremely difficult and has been argued by some to be impossible (Gallagher, 2012).

Heidegger argued against objective human science and the ability to remain objective as a researcher (Heidegger, 1962). I tend to agree with this theory and as the researcher I must come to accept that parts of my own personal understanding are reflected in the interpretations of this study. Alfred Schutz recommended studying the subjective realm in an objective manor (Schutz, 1970) and that is what I believe I have accomplished.

I identified that accepting my subjectivity was critical to the success of this research. I do see value in eliminating biased results from my participants to uncover a pure interpretation, but preconceptions are a part of the conscious experience which I have analyzed and interpreted. Consequently, I have avoided expressing 'what I think' responses should be with verbal or non-verbal cues to the interviewee.

Using Constructivism

The constructivist socio-cultural model of Howe & Stubbs (1997) inspired this qualitative research project. Howe and Stubbs (1997) used the constructivist sociocultural model to explore individual relationships to teaching as connected to self-awareness and experiences in the classroom. By adapting prior knowledge to new experiences, teachers construct richer perspective and information. Constructing new knowledge in a supportive professional environment has resulted in changes to pedagogical approach (Howe & Stubbs, 1997).

The constructivist approach was utilized to build support structures for teachers based on their own personal views and requirements to teach science. Constructivism research illuminates the participants' views of the situation being studied (Creswell, 2013) and can be implemented to respectfully address the alternative perceptions shared by teachers involved in the research. Each participant's responses in relation to their personal views of self-efficacy in teaching science were critical to the results.

Other Qualitative Methodologies

There are many other qualitative methodologies concerned with human experiences. After reviewing the benefits and limitations of these frameworks I defend my choice of phenomenology as the best fit for my study.

Narrative study. Narrative studies begin by expressing lived experiences, and interpreting meaning in these experiences (Creswell, 2007). Narrative studies collect information with an informal strategy directed toward no particular topic and require extensive information on the participant being studied (Creswell, 2007). Narrative studies tend to focus on the life stories of only one or two individuals (Creswell, 2013). The focus of this research on the other hand was primarily on the phenomenon of teaching inquiry-based science in elementary school by analyzing the lived experiences of teachers. Thus, I was not exploring teacher experiences through a narrative framework.

Case study. A Case study investigation is an in-depth study of a specified situation used to narrow down a very broad field of research into an easily researchable subject (Creswell, 2007). Case studies have similar intentions as phenomenological studies, but the most evident difference of these methodologies occurs in the number of participants involved. In this context, a case study would require only one participant and I felt that to analyze this observed phenomenon, teaching inquiry-based science in elementary schools, more than one participant needed to be involved to gain the best interpretation of the lived experiences (Creswell, 2007).

Action research. Action research is derived from a similar framework to phenomenology. The goal of using action research is to promote a reflective stance and a self-monitoring device for researchers to critically examine their practice to improve (Mills, 2006). Teachers often use action research methodologies during studies of their own classrooms (Creswell, 2013). The researcher doubles as a full on active participant as well. However, I was not the participant in this study, nor was I studying my own teaching context and therefore action research was eliminated as it may not have proved to be productive in answering my research question.

Phenomenography. Phenomenology can be easily confused with phenomenography as both methodologies analyze participants experiences of a given phenomenon (McMillan, 2011). Phenomenographical research aims to identify multiple meanings shared by a specific group of participants (Gallagher, 2012). This design also requires the researcher to eliminate any inclusion of their own firsthand experiences with the phenomenon. I have trusted that my experiences bring value to this research and resulted in a richer understanding of the phenomenon, so phenomenography did not fit my desired framework.

Ethnography. Ethnographic studies attempt to illuminate the socio-cultural disposition relating to phenomenon being studied (Creswell, 2013). The focus does not rest on the phenomenon itself, but on the political and cultural meaning behind a given event. The data collection methods for common ethnographic research are similar to those utilized in this study, such as interview and journals (Creswell, 2007). Overall the aim of an ethnographic study would be to interpret a situation of social injustice and I did not believe that to be the case in my research.

Research Design

Research Context and Locations

***Phase 1*:**

Phase one involved two full day science education workshops, structured in October of 2017. These sessions provided professional development for 14 local teachers. These teachers were informed of the research study and asked to voluntarily fill out a consent form at the beginning of the session and a brief survey at the end of each session. The survey was designed to offer some baseline information that helped contextualize how they respond to the science education workshops and inquiry-based science. The survey asked questions that can be found in Appendix A.

The inquiry-based science activities involved in the workshop were approximately five hours long. I distributed science notebooks to these teachers which they used as activity logs with a POE technique (predict, observe and explain). I collected the workshop surveys and journals from the teachers at the end of the session and use them as data to contribute to the development of themes. Teachers did not use the journals to record experiences. Instead, they used the journals to create sketches and observations of the activities they were involved with. The journals proved to be an invalid source of data as they failed to contribute to topics and themes of research analysis. The journals were meant to capture experiences, but teachers appeared to misinterpret this tool. The surveys contained what I believed to be vital information in this study based on the compilation of experiences that this phenomenological study depends upon.

***Phase 2*:**

The second phase was an extension of these professional development workshops. Teachers were invited to participate in an extensive one-on-one interview session during December of 2017. The purpose of these interviews was to discuss some of their experiences in the workshop in relation their previous experiences teaching science and identify links to how this has affected their self-efficacy, if at all. These interviews were held in each participant's school at a time and in a location of their convenience. Three teachers who agreed to participate in this phase of the research were interviewed and all information about their persons kept confidential. Interview participants signed a consent form as found in Appendix D. The pseudonyms Ashley, Gloria and Sam were adopted to anonymize the participants.

Role of the researcher. Throughout this study my role has slowly evolved. My contributions as the workshop facilitator were maintained as professional and supportive to encourage participants to discuss the subject matter they felt needed to be better understood. My role as facilitator of an inquiry-based workshop positioned me to be biased as a promoter of inquiry-based instruction in science classrooms. Guiding questions directly stimulated discussion about elementary science teaching attitudes, experiences, and perceived needs. I continuously collected information through personal observation and note-taking of the participants during the workshop to prepare for the one-on-one interview sessions.

During the interviewing sessions, I acted as the interviewer. I limited my contributions to the discussion during the interview, yet I was required to prompt the participants for further explanations and detail as they respond to the interview questions. I found this process became easier over time as participants often tended to attempt to interpret their actions and experiences. These sessions were audio recorded and later transcribed by myself.

Data collection. In depth interviews are the most common method of phenomenological data collection (Moustakas, 1994). Interviews were extensive and open-ended in hopes that participants would offer me some sense of how they develop self-awareness about how their beliefs impact their teaching decisions in the classroom. Additional methods of data collection included workshop surveys, workshop observations, reflections by the researcher on the workshop process, and artifact analysis; all methods reported by McMillan, (2011) as data collection strategies employed by phenomenological researchers. After collection and interpretation of information, the one-on-one interview transcripts and workshop surveys proved to be the richest sources of data and were used further to develop themes for this study. Artifact analysis and workshops observations were helpful towards planning interview questions and future workshops but were not valuable for informing the themes developed in this study and thus, were not a focus of the data analysis.

Data set 1: workshop surveys. After the workshops were completed, teachers voluntarily completed short surveys. This data set illuminated some of the challenges and misconceptions these participants share in teaching their science lessons. The questions asked on these surveys can be found in Appendix A. I used survey results from the workshop to formulate interview questions and themes moving forward in this study. Guiding questions for one-on-one interviews can be found in Appendix B.

***Data set 2: one-on-one interviews*.** The second set of data collection took place through one-on-one interviews. Interview dates were arranged via email with the participants who identified themselves during the workshop survey questions being the participants contacted. Interview sessions began with an introduction of myself as an educator, researcher and as the interviewer. I delivered a detailed explanation of my research study and described their role as a teacher participant. Participants were reminded of their option to remove themselves from the study at any time.

Participants were made aware of their identification by number in the study and that they were being recorded by audio tape.

The interviews had been scheduled for an hour block if necessary. Interview length varied from approximately 30-45 minutes based on the time teachers had to spare and the depth of contributions they had to my questions. The interviews were semi-structured in order to ensure that key concepts were discussed (Appendix B) while leaving some wiggle room for tangential discussions.

Participants were given a freedom to discuss the elements of science education they are most effected by. The phenomenological methodology required questions which targeted the experience of the participants in this study (Husserl, 1970). To maintain a trusting environment, I refrained from interjecting my own opinions or experiences, though this proved to be difficult at times.

Participant Recruitment

The participants were selected on the basis of their experiences with the phenomenon in question. Participant experiences with teaching science are further described in the results section. An invitation was sent out to elementary school teachers of grades three to five in the Anglophone West School District. The invitation welcomed these teachers to attend two free inquiry-based science workshops scheduled for October 2017. The workshops provided observational data to the study, and just as importantly, introduced me as the researcher to a group of potential participants. This invitational email can be found in Appendix C.

The workshop participants volunteered to share their experiences working in the public education system here in New Brunswick. To be selected as participants, the teachers had to have experience teaching elementary level science, preferably through grades three to five. The teachers varied in age, years of teaching experience, science content knowledge, and personal feelings of confidence with science teaching.

Phenomenological studies typically include numbers of participants that range from 2-10 (McMillan, 2011) and in this study, I interviewed and uncovered the experiences of three local elementary school teachers. Teachers had the option to share their email and other contact information on the workshop survey form. The selection of these participants allowed me to interview the most diverse group of participants (i.e. teaching experience, confidence level, pedagogical approaches, etc.) though they needed to have experience teaching science in grades three to five. Teachers selected were asked to volunteer their time in December of 2017 to sit down for one-on-one interviews. After the interview process, these selected teachers were given pseudonyms to protect their privacy as participants of this research.

Group Size and Location

Creswell (2013) recommends the researcher utilize small group sessions in purposely selected locations which can best inform the researcher about the problem. Workshops were held in a spacious classroom located in Marshall d'Avray Hall at the University of New Brunswick. Tables were arranged to provide six separate engaging inquiry-based science activities while keeping mindful of participant movement and visibility for the researcher's observations.

Eleven of the fourteen teachers participated in the workshop survey. One teacher was discovered to be a middle school level teacher and was therefore left out of consideration for data collection questions concerning elementary level science instruction.

One-on-one interviews took place at the most convenient location possible for participants. All three participants chose to give these interviews at their school either after class or during a break period. I asked permission from the school district, administration and teacher before conducting these interviews on school property. The participants were given very flexible range of dates to choose from.

Member Checking

After the data collection process had been completed, member checking (McMillan, 2011) was used and a copy of each participant's data was made available to them electronically. Participants retained the right throughout the research process to withdraw from this research. Data analysis was completed following a conversation with each participant regarding their impressions of the data that originated from their participation.

CHAPTER 4

"It ain't what you don't know that gets you into trouble. It's what you know for sure that just ain't so"

Unknown Source

Results

In this chapter I will present the challenges uncovered via the workshop teacher survey questions and then explore teacher responses to these challenges through one-one-one interview conversations. The qualitative data will be displayed in two sections, one for each data set. Typically, interview responses were a richer source of phenomenological data in this study, thus, have been broken down further to offer a deeper construction of the teachers' experiences.

Identifying Challenges through Teacher Survey Results

Resources. When asked about the challenges in teaching inquiry-based lessons, six of ten teachers surveyed mentioned a lack of resources or materials as being problematic. These teachers confirmed having access to supplemental materials such as, 'The Science Cycle' and even some basic science unit kits. Teachers were not only aware of these tools, but they appeared to be familiar with the expectations required of them to teach with an inquiry-based pedagogy.

The materials teachers do have access to do not seem to be specialized for science measurement and experimentation. Many participants believe that inquiry-based science instruction requires these specialized materials directed to scientific experimentation rather than dollar-store consumables they currently have access to. Teachers did not offer specific examples for what specialized materials they require. A few responses suggest that teachers frequently pay out of their own pockets for materials to perform classroom experiments.

Time. Time was another challenge identified in the teacher surveys. In the positive feedback section of the survey two of ten teachers praised having time during the workshop to examine and explore inquiry-based science instruction and suggested that such reflective time does not fit into the typical school day with their students. Only two surveys suggested time allocation as a challenge of teaching inquiry, however, several mentioned frustrations with setting up, facilitating and monitoring experiments that extended longer than one science class. Teacher survey results were averaged and according to the results, 2.1 science classes occur per week with 135 minutes of science per week overall among the fourteen participants.

Knowledge of inquiry-based instruction. A portion of the survey questions focused on the general understanding and use of inquiry-based science instruction. Only three of the ten teachers surveyed admitted to using inquiry often while several claimed they do not do as many as they should, or they plan to do more next year. Teachers responded that they a lacked an ability to make connections between activities/experiments and expected outcomes/curriculum goals. Some survey responses requested that a professional visit their classroom to perform a walkthrough inquiry-based lesson or a 5E lesson plan.

Five of the ten teachers felt confident with the content they have taught. Two of the ten students who felt confident with content knowledge responded with confusion regarding the inquiry-based pedagogy. Regarding teacher education, four of the ten teachers never took science courses in university. Three of the ten took only elementary education science class with their education degree while the other three took additional science classes in their undergraduate coursework.

Classroom management. Eight of the ten teachers suggested classroom management or facilitation limitations as a major challenge to using inquiry-based pedagogy in science. Concerns included keeping students on task, using materials properly for experiments, supporting students with special needs, large class sizes and even language barriers with early French immersion students. Most participants believed inquiry-based science may lead to a chaotic classroom environment.

Expanding on the Challenges through One-on-One Interviews

Survey responses were used to generate a list of guiding questions (Appendix B) to ask during three in-depth interviews with the selected participants. The three teacher participants who gave one-on-one interviews are addressed by pseudonyms in this study. I have randomly assigned pseudonyms and included some relevant, non-identifying traits as an educator (experience level, school location, grade taught, etc.).

Teacher 1 - **Ashley**: Two years teaching experience, rural school location, grade five teacher, no science courses taken during university.

Teacher 2 - **Gloria**: Over ten years teaching experience, rural school location, grade four teacher, some science background and university course work.

Teacher 3 – **Sam**: Over ten years teaching experience, urban school location, grade five teacher, no science courses taken during university.

Challenges with materials and resources. According to interview responses, teachers were familiar with several resources at their disposal. This included a curriculum program guide, consumable supplies, and, in one case, a unit resource kit. However, it did not appear that all teachers were privileged to these kits as one participant, Ashley noted, "it takes effort to go out and buy all the supplies". Ashley continued to mention that in previous years there had not been enough materials available for experiments, which resulted in only half of her students participating while the others observed. Sam suggested, "I don't have enough resources to do what I would like to do with science in a classroom because I like to do everything well or don't do it at all".

Are these resources efficient? The curriculum guide was declared to be helpful but not always easy to translate into activities and experiments. Ashley struggled to translate the 'how to' of the curriculum guide into a lesson plan with hands-on experiments. As a new teacher it was apparent to her that some science resources or unit kits were not readily available.

One of the more experienced teachers, Gloria, had accumulated many non-fiction science books, consumable materials and even a unit resource kit. The two other teachers, Ashley and Sam, had no such resources and looked elsewhere for this type of aid. Ashley explained, “when I first started teaching science I was going to that program guide which is kind of like a curriculum”, she said, “It will explain how you can do something, but you have to make a lesson from it. And it took me like an hour to make up a lesson plan”.

Sam learned how to cover the science curriculum from a co-teacher with more experience. Sam shared her experience in her interview,

> Another teacher said to me that worked here once, hand out the workbooks to the children and have them look through and then have them choose an experiment they want to do and they can work on it with a partner and then they present it to the class. So that when you’re done all the experiments are done. Like they’ve seen all of them.

Sam expressed that she had no other sense of direction to take so she followed this suggestion blindly.

What external resources teachers access? There were many external (outside of school curriculum) resources mentioned in the three one-on-one interview sessions. These resources varied from parent supports, classroom outings, free outreach programs, internet sites and videos.

Sam had spent nearly ten years delegating science lessons to outreach program instructors such as Let’s Talk Science – UNB, a free service in which university science students would come into local classrooms with resource kits and planned activities.

When asked how this resource was discovered Sam responded, "well, I got an email for the Let's Talk Science and asked 'are you interested' or whatever, and someone actually got back to me". After a few years of Let's Talk Science visits, Sam found an alternative outreach partner through the Renaissance College. This instructor partnered with Sam for no charge as it was part of a program requirement. The outreach partner came into the class and taught a unit on fitness and health. Though Sam has been incredibly resourceful, she admits that if asked to teach science lessons tomorrow she would 'freak out' from the fear of teaching science that persists after more than ten years in the classroom.

Gloria shared her experience accessing resources for science activities. She reached out to the community and parents of students for help.

> I started at a small school and there wasn't much for resources, so it was just it was just something you instinctively did. Parents were very involved in that school, so I think probably a lot of times they would notice we were doing something and offer… I'll send out a letter home before we start the unit and just explain to parents this is the unit that we're starting… we can explain to kids 'I need to know how do this because when I grow up I might wanna be this'. So, I've always sent a letter home to kind of engage parents and have them if they have anything that they could share.

Gloria was lucky enough to encounter parents of her students that were professionals in the scientific community such as a geologist who aided with her 'rocks and minerals' unit. She recalled that, "there was a father that was a geologist that got some, had some other samples for us". Gloria went a step further and utilized the internet websites provided in the curriculum while also getting out of the school to visit the geology department at the University of New Brunswick. "We went to the geology department and actually did a very similar activity where we rotated around and there were even more stations that I could have done with the kids so that was exciting you know to see that oh I could of, you know, this was another one I could have done".

Ashley pointed to science videos as a source to compliment the units she teaches. She stated, "I like doing the Bill Nye to either sum up a unit or to start off. Just as a, like, to get the kids engaged or sometimes it's a good summary and I can have them answer questions along with the video".

Sam and Ashley had previously reached out to the UNB faculty of education to access 'Science unit in a box' kits developed by Dr. Ann Sherman and myself. They describe the kits as easy to follow and adaptable. The kits included prepared lesson plans with all consumables directed toward inquiry-based activities. Ashley noted, "I do a lot better if I had something right beside that I can make to get all the 5 E, I think the best one to follow", suggesting that the 5E lesson plans promote the planning of inquiry-based activities. Sam recalled,

> Those kits that you brought in… Like if every school had those then we could say 'alright this is what we're gonna do, were gonna spend the whole afternoon,

> we're gonna set up stations here'. You know what I mean? That would be almost considered a whole unit because you could cover so many things.

Resource and material discussions included videos, unit kits, classroom outings, outreach programs, curriculum guides, amongst others. These resources were not consistently present in the three locations I conducted interviews and often required extra work and initiative to access.

Challenges with time and planning. Extra hours of work came up through teacher surveys and interviews. I asked teachers to describe the process of planning lessons and scheduling science into their students' school day.

How does science fit into the elementary class schedule? I asked the three participants to describe their process of scheduling science into a weekly class schedule. "You have start and make sure that you have your math and literacy minutes first. Minutes that are left are split between science and social studies", Gloria stated. She added that, "mornings are normally literacy times. You usually end up with your science and your social studies in the afternoons". Sam mentioned,

> It [science] would be in the afternoon. Because to me the language arts and math have to be when we have the children's most attention and brains are functioning at top notch. So, I have to do my language arts and my math in the morning. So, science gets relegated to the afternoon.

Ashley plans her science lessons around prep time, "I like to do science when I either have time before or after to like set it up". She went on to affirm that mornings are the best time to instruct literacy, “yeah, I do like starting off with literacy because I like them reading when I come in”, she continued, “I probably would keep math in the afternoon and then science just wherever I can have time to set up or clean up. For me it doesn’t make a difference what time it is”.

What barriers arise in scheduling science lessons? Gloria was quick to point out scheduling conflicts when attempting to allocate enough time to complete an experiment, “you might need to make a double period so to get through an experiment, so you’re gonna make your math and science that day and the next science period you’re gonna give it back to math”. She added, “so, when you’re starting out you have to think about ‘do I need a double science?’, I should have it right before prep, so I can get my materials organized before the kids come in”.

Gloria also described a lesson planned and delivered to her class by the science lead director of Anglophone West School District. She was thrilled about the lesson but went on to question, “how much time did it take you to get this lesson ready for us? Because I have six other classes I’m teaching today and if I put this much into all of them I would never have a life”. Ashley shared this concern for planning and preparing inquiry-based lessons, “it’s a lot of planning to set up stuff for experiments, so if you’re short on time…”.

Ashley noted about the curriculum guide resource, “I just didn’t know where to put everything or how to have like, a hook or I don’t know… how to break it up”. When asked if she could get help or guidance from other teachers at her school Ashley described,

> I feel like I can talk to anyone at this school, but they teach different grades, so they might not directly be able to help me with my grade. They might know of some people I can contact, and there are some teachers at other schools that I could contact but sometimes it's hard to. If you have to physically go somewhere just to get the time to make yourself do it.

Gloria learned from past experiences to plan her units by season to include inquiry-based opportunities for her students. Gloria stated,

> We're not gonna do 'soil' in February or you know things like that. So, you kind of think we'll leave 'light' and 'sound' for in the winter time and do your 'rocks and minerals' usually when school starts, and then you save your 'habitats' for the spring because we do the butterflies every year and the meal worms and all that. So, that kind of ties in and that's the time of year you get them, so you have to be thinking about all that stuff happening when you can plug it in.

Sam recalled an interesting conflict. She spoke of a "really strange situation" in which she co-taught a grade five science class. There were inconsistencies as she mentioned, "I was teaching it half and half with somebody else. So, we were like 'how do I do this?'. Am I leaving an experiment half way through?". Sam was unclear how the children would comprehend the experimental design with two instructors sharing the responsibility of directing the lesson.

Ashley described a common problem amongst grade five students in this school district. 'English prime' students spend half of the year in French immersion class in which no science is taught. Therefore, Ashley and teachers in her same role must compress all the science curriculum into half of the school year. Ashley explained,

> In February I think I have two hours a week of science, and I have two units and I have… five months. So, I try to plan like one unit of two and one unit over two (months) …. I know I'm gonna go over with the first unit, so I plan for two months and then I have a bit of wiggle room…. I try to plan it out week by week more to make sure I get it all in.

The participants shared a common sense of when science fits into their schedule. They all expressed intimidation with planning and cleaning up after inquiry-based activities.

Challenges with professional development and teacher education. The conversations with Ashley, Sam and Gloria had many similarities. One of these re-occurring themes was experiences with professional development and college course work. I allowed my participants to voice their opinions and feelings about being prepared to teach elementary level sciences.

How are teachers professionally prepared? My participants did not share a collective experience through their teacher education programs, yet there were similarities. Sam took her university teacher education over twenty years ago and recalled, "there was one 'how to teach science' course, but I don't remember being enlightened any by it". Contrarily, Ashley studied to become a teacher only three years ago, but she shares the same sentiment of her 'elementary science education' course, "I just found it didn't prepare me for teaching". Ashley's course was once a week during the year of her program. She expressed that this was not enough time to prepare her to teach science the way she is expected to.

Gloria was unsatisfied with her teacher education experience concerning science instruction. She shared that, "it wasn't university level… 'why are we doing things we've already done in high school', because that's pretty much what it was". Gloria is a teacher who feels confident with science teaching at her level, but in her opinion, teacher education preparation was unfulfilling. I asked Gloria if there was any talk of inquiry-based learning at that time. "No, he set up the labs and we participated in them and even we had to write some lessons and make up a lesson for a certain theme or whatever".

Ashley participated in science education course work more recently, so I was eager to hear about her inquiry-based teaching experiences. She remarked, "we did do hands on, so in that way we got to experience being the student". She continued to critique her experience stating, "I guess I would have liked to see her model teaching the lesson. Like she'd give us activities to do like as if she were the teacher. Because she would have us co-teach stuff, but I guess that's what I found was lacking was in the education program". Ashley continued, "I would like to see the model and also see several lesson plans that they do before we do it. We didn't have a model all the time".

What PD opportunities are available for elementary science education? The teachers interviewed partake in ongoing general professional development programs through their school and district. I personally had never heard of a professional development program focused on teaching science at the elementary level here in New Brunswick. Gloria mentioned an experience in which the science lead of her school district visited her classroom. She recalled, “he came with a lab coat on. He looked the part you know what I mean?”. Gloria described that, “he had set up stations and it was like formulate, like we had a discussion, questions came up and then we had that freedom to test”.

This experience involved a classroom of students and many onlooking teachers. “I could see like we were engaged as teachers”, Gloria explained, “it kind of turned me around then as to think I don’t just have to wait until high school to do these kind of things with the kids. It doesn’t have to be as directed you know and give them those opportunities”. Gloria’s opportunity to observe an inquiry-based lesson offered her tremendous value. Unfortunately, Sam had no such experience in her more than fifteen-year teaching career. Sam told me, “when it comes to PD for science I haven’t heard of any”. Soon after she remembered that two of the teachers from her urban elementary school were able to attend a session. “It was for grade three to five. There was two representatives sent from this school”, Sam stated. She continued, “I said ‘anything you can get for grade five let me know… like anything you can get for grade five’. So, I was really hoping to have something. Like give me something a pamphlet an outline… give me something”.

Science education workshops and professional learning opportunities are available for teachers. Teachers seek out these opportunities independently as they often occur during non-paid hours. The three participants interviewed in this study might be perceived as 'proactive' on the basis of their effort to attend the unpaid weekend workshop involved in this study. I was curious to know how these teachers discovered these opportunities outside of their working environment.

Gloria pointed out that the administration team at her school promote these learning options via email. She described, "they're constantly sending things out you know, a little note, 'thinking this might be something you'd be interested in". Ashley echoed this response indicating, "I think there was an email sent out. I think, yeah, there was an email, and I signed up because I was like 'oh my goodness this is good', I need to learn how to teach science". She expanded by claiming, "I know it's expensive, but it would be nice if there were workshops even if it was once, twice a year for teachers to have release time to go to". Ashley referred to 'release time' in which teachers could take these workshops during their paid hours.

Gloria mentioned her experiences with university workshop opportunities. She recalled, "doing those activities and encouraging us to do inquiry-based and showing us how cross-curricular it can be and how you can have all these things going on and be doing so many more things other than standing at the front of the room and doing one experiment and everybody watching".

Challenges of understanding science and inquiry. The most difficult point of conversation was eliciting the participant's relationships and confidence with science and science instruction. Teachers were eager to suggest challenges outside of their control while it took some encouragement to discuss the individual feelings and experiences of self-efficacy.

Do teachers understand how to do inquiry-based instruction? I received many positive comments on the effects of inquiry-based learning from Gloria, Sam and Ashley. Sam reflected, "to me it's being able to move around and then it's always the shock factor… mixing things together 'ohhh what's gonna happen'. It's exciting. I can totally understand it". She continued to reinforce the importance of inquiry, "I guess when I did science growing up they didn't do stuff like that". Sam was able to identify essential elements of inquiry-based learning, "they want the kids to follow a process now, like write down a hypothesis, what they did and like the question, what they're gonna do to try and figure out", she continued, "you have to keep one thing the same all the time so that we know that the experiment will work. Doing it once doesn't mean that that's the right answer you have to do it more than once".

Gloria was very confident with the methods of inquiry-based instruction. She described, "there's not a right or wrong to it. Their results might not be what it is in the text book and why? What can you find out about that?". Ashley indicated her own liberation of better understanding inquiry-based instruction through workshop experiences, "it's actually really fun once you start doing the hands-on approach and then you actually feel like you don't need to know as much because you can pretend you're just discovering with the kids". Ashley explained her knowledge of inquiry after university level education, "in the education program they did say, like my prof did say, like science you're supposed to let them kind of discover it whereas in math you kind of have to teach it to them".

Gloria expanded her reflection to the effect these activities have on her students' home life, "and they'll go home and come back and say we've tried this at home, and that's cool because their parents are involved then too right?". For Sam things are a bit different. She was able to identify moments in her life when she uses scientific thinking, "I think being in a classroom I experiment everyday… what things are gonna work with my kids and what are not, right?". However, Sam then went on to announce, "if someone seriously had to come up to me and say 'so what's your relationship to science?' I go, 'uhh yeah I don't have one'. I would seriously say I don't have one".

Sam talked about, "the way we were raised" and how "years ago that's how science was perceived" when discussing her disconnection to the scientific community. "Obviously I do things every day that involve it (science), but when I think of education I'm thinking I'm supposed to be teaching these children something about how water can be a solid and a liquid. You know what I mean? That's the way I think of science". She shared a strong statement about a missing link between these exciting hands on activities and the curriculum outcomes, "could I write down specifically what the kids are learning there myself? I don't know. But I know it's part of science, so if I taught it I'd be ok with it I just wouldn't be able to tell you objective, outcome".

Ashley had a mixed explanation of inquiry-based activities. She admittedly had little experience teaching with an inquiry-based pedagogy. She described, “I think the experiments are because it was the liquids and gases, so they’re mixing things and they see what it forms”, Ashely continues, “if it changes like a paper clip if you bend it it’s still the same thing but you’ve changed the form, but then like making the slime you’re mixing two substances and it creates something different”.

Are teachers confident in their science knowledge? As mentioned previously, Gloria expressed confidence with scientific knowledge. She suggested, “I probably would accept something more if it were scientifically proven” indicating a level of trust and confidence in the scientific process. Ashley shared this trust in scientific research, especially in the medical field. Ashely described her confidence with science knowledge,

> I enjoyed doing biology and chemistry in high school, but I didn’t do any science at all in university. So last year when I had to teach science, and I didn’t do any science in my internship. I was actually really nervous to teach science because I didn’t feel like I knew much about science at all and I didn’t feel comfortable with a lot of the vocabulary. Like I had to learn it before I taught it, so that’s why at first I wasn’t doing much experiments because I felt I didn’t know anything.

Sam shares this sentiment of fear related to science. When describing her reaction to having to prepare a science lesson plan for tomorrow, “if I had to do it like right this minute there? I’d freak out first”. Sam recalls feelings of loneliness throughout her high school and university science course work. She then expressed her confidence as a science teacher for her students, “I’d have to say ‘uh I’ll have to check on that for you’, or ‘I’ll have to ask someone’, which I’m totally fine doing”. Instead Sam suggests bringing in support, “you don’t need to be an expert, but someone that knows about the subject, you know, in here it’s a lot better, right?”.

Do teachers avoid inquiry-based instruction? Sam has admittedly been avoiding teaching science for over ten years. She remarks, “I just don’t feel that I have enough information to do with it what I’m supposed to do in a classroom”. Ashley expands this reaction by suggesting, “you’re gonna default to just teaching about science or watching Bill Nye the science guy”, referring to using videos or the didactic approaches of the past. Ashley shared concerns for mismanaging an opportunity to implement the inquiry-based method in her classroom, “depending on the question like you could Google it, but it would be nice if like I could find an experiment that they could find it out instead of just answering through the internet”, she elaborated, “I would probably just go and Google it, but in hindsight it would be better if I could make a little experiment about that”.

Challenges with classroom management. I was curious to know if these participants would expand on the results acquired from the workshop survey and suggest that classroom management could restrict the use of inquiry-based teaching. The interview responses did not reflect these findings.

Gloria was the only teacher to touch on classroom management, and she did so in a positive manor regarding inquiry-based activities. Gloria uses inquiry-based experiments and activities as reinforcement for students with behavioural plans. She described, “we have a little boy at end of the hall that’s not in class at all and his reinforcer is testing rocks”, Gloria continued, “they’ll come and get the streak plates and all that stuff from me, so that he can because he relates with that he really enjoys that”.

Summary of Results

Many challenges have been identified by both teacher survey responses and extensive one-on-one interview conversations. The findings illuminate recurring themes such as, the lack of confidence teaching science, the desire for ‘quick fix’ science teaching solutions, alternative perceptions regarding science, a disconnect between perceived curriculum goals to the inquiry-based experiments, and teachers giving their own money and time for resources or learning opportunities directed at science teaching.

These themes have been interpreted and compared with the challenges established previously in the literature review. The significance of these findings are discussed along with strong recommendations to alleviate the challenges facing teachers and improve the elementary science education experiences of both students and teachers.

CHAPTER 5

"Every kid starts out as a natural-born scientist, and we beat it out of them. A few trickle through the system with their wonder and enthusiasm for science intact."

Carl Sagan (Psychology Today, 1996)

Discussion and Recommendations

The findings of this study display a set of patterns surrounding my research question, **what challenges do elementary school teachers encounter when implementing inquiry-based instruction while teaching science in New Brunswick schools?**

Some of these challenges were 'surface issues' in which teachers did not feel directly responsible (finding 1). Other challenges suggested an underlying paradigm which teachers could not consciously identify or explain (findings 2, 3 and 4).

Findings in this study include;

1. Teachers indicated inconstancies regarding resources available to teachers of the same school district.
2. Elementary school teachers in this study expressed alternative perceptions of science which impact self-efficacy and motivation to improve teaching.
3. Elementary school teachers in this study struggled to connect inquiry-based activities to curriculum outcomes.

4. Elementary school teachers in this study desired a quick-fix, 'cookie cutter' solution to improve their practice which contradicts the theoretical purpose of science and experiential learning.

SURFACE CHALLENGES

- Inconsistent resources
- Lack of time
- Dissatisfaction with preservice training
- Classroom management

LATENT CHALLENGES

- Lack of agency to improve
- Alternative perceptions of science
- Disconnect between inquiry and curriculum
- Desire for an easy fix to a complicated problem

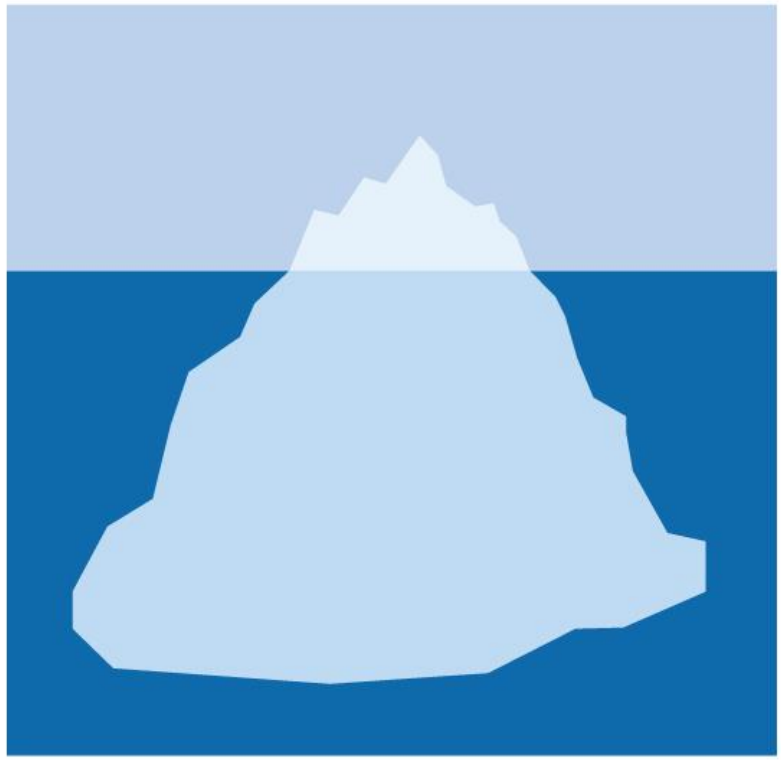

Figure 2: **Findings are divided into two groups; surface challenges and latent challenges. Surface challenges were easily identified and explained by teachers, while latent challenges were revealed through interview analysis and interpretation.**

Surface Challenges and Latent Challenges

Participants were very aware of 'surface challenges' such as a lack of materials, not enough time, and/or concerns about classroom management. These challenges were partially out of the teachers' immediate control. Therefore, teachers felt no independent responsibility to resolve these challenges. More compelling and complex were the underlying latent challenges that participants were not always aware of.

These barriers included alternative perceptions of the science, alternative perceptions of teaching with inquiry and the desire for a quick-fix method to teaching inquiry-based lessons thus defeating the purpose of learning what science and science education is all about. I believe these latent challenges contribute to teachers struggling with inquiry-based elementary science much more than surface level issues.

Though surface level issues such as dissatisfactions with teacher education are critical, I believe the psychological barriers and alternative perceptions that teachers develop early in life are more impactful. The iceberg analogy (figure 2) can be used to describe the easy to identify challenges on the surface and the submerged latent challenges that cannot be identified without diving under the surface to explore.

Finding 1: Surface Challenge – Resources Issues

Qualitative data from this study suggested inconsistencies in teacher resource accessibility, teachers paying for materials out of their own pocket, and schools lacking specialized scientific equipment. These challenges have been labeled as surface level based on the participant's level of awareness to the problem.

Teachers paying for materials. I have heard of teachers spending their own money for science consumable materials. This is unfortunately a common occurrence at the elementary school level. In my professional experience, inquiry-based science activities require teachers to have access to resources that are not often found in New Brunswick schools. This requires teachers to go to the store outside of school hours and pay with their own money, or to look for free outreach opportunities which are available but require planning and flexibility in schedule. These occurrences were confirmed by survey and interview results, and they need to be identified at the district level.

Resourceful actions of teachers. Though teachers struggled to teach the science curriculum, they often found very resourceful resolutions. Gloria, Sam and Ashely spoke of utilizing parents, field trips, science outreach programs, videos and peer coaching. Many of these alternatives were mentioned in the review of the literature as workable solutions (Van Driel et al., 2001; Houseal, Abd-El-Khalick & Destefano, 2014). The resourceful actions of teachers helped alleviate the pressures of science teaching, but they did not seem all that effective as methods of improving the practice of teaching inquiry-based science or improving a teacher's relationship to science (Falloon, 2013). This reflects on finding 4; teachers seeking a quick fix solution rather than looking to improve professional skills.

Inconsistent resource availability. Within the findings of this study, inconsistent resource availabilities were the most common surface challenge to be identified. Considering that teachers are expected to teach the same curriculum, all teachers of the same grade and district should certainly start with a set of functional resources and outreach options. I do not believe that every teacher should be coached to teach science the exact same way, but an imbalance or streaming of student opportunities may occur if only some of these schools are implementing unit kits and others do not.

Gloria considered herself fortunate to obtain a resource unit kit for her grade 4 science class. No other participant survey or interview responses mentioned having access to science unit kits. Research on the effect of inquiry-based resource kits are mixed (Jones & Eick, 2007; Bhattacharyya, Volk, & Lumpe, 2009) as some suggest that every individual teacher will implement these resources in their own way (Van Driel et al., 2001) with some teachers improving and others deteriorating their science teaching practices.

Resource kits. I have spent many years working with teachers and developing inquiry-based support kits. Originally, I thought these resources could help teachers in their practice, but through my research I have come to believe they could be a hindrance to understanding the purpose of science. To become proficient with a skill, one should learn through experience and interconnection. Essentially, if students learn science best through the hands-on inquiry style, teachers will also learn to understand and teach science best with that approach.

Teachers with an appropriate perception of scientific tools can successfully operate kits (Jones, Robertson, Gardner, Dotger, & Blanchard, 2012), but the quick fix model of ‘everyone gets the same kits’ may not lead to efficient science teaching. In New Brunswick we have adapted the ‘Daily 5’ literacy cycle (Boushey & Moser, 2006). These cycles tend to be successfully implemented and teachers adapt them to their preference. Many elementary teachers have a strong background in reading and writing which strengthens their ability to implement new literacy-based pedagogies or programming. Without a general comfort and understanding of science these wide spread, generalized resources could fail.

Specialized materials. Surveyed teachers suggested a need for specialized materials. Teachers were not specific through description, but I wonder if they are referring to microscopes, magnifying glasses and other general 'science' tools. Though I believe these tools are useful and fun for students to interact with, I do not believe they are necessary to do good science. While practicing with a plastic pipette or a mineral testing kit can be beneficial, in my experience creating inquiry-based lessons with cheap consumable materials can be equally effective tools to design experiments, measure and observe results. Specialized equipment tends to be very expensive, as are most 'science' directed educational kits or materials. I believe teachers think that using specialized equipment and dressing up in a lab coat will generate the illusion of doing science. A lab coat or a microscope are not solutions to designing effective experiments or to answer inquiry-based questions.

Finding 2: Alternative perceptions of Science

Interview responses suggest that alternative perceptions of science exist among elementary teachers. These results support previous research of teacher relationships with science (Abd-El-Khalick, 2001; Gess-Newsome, 2002; Lederman & Abell, 2014). Examples of these alternative perceptions include, believing that scientific theories are indisputable facts, and believing that hands-on science is the same as inquiry-based science. Alternative perceptions are developed through lived experiences, societal norms and the presentation of science through other various platforms including television, internet and the news (Schulz, 2014).

The alternative perceptions. Participant beliefs about science were rigid and positivist. Gloria, a teacher with confidence in teaching science, gave a response indicating that science “proves” theories. Gloria failed to acknowledge that science is a tool used to test and disprove hypotheses to hopefully make better sense of the world we live in. Gloria also failed to mention that science can result in error or inconsistent results. Gloria and other participants were misguided by a fact-based, positivist perception of science that seemed to cause a personal disconnect from their lives.

Sam and Ashley were more forthcoming with their discomfort in recognizing the purpose of science. Sam described the process of being a teacher and her struggles of trial and error to keep the classroom running. In Sam’s next thought, she described her disconnect to science and the knowledge associated with science. She was unable to make the connection between her thought process of planning and preparing for her class and the nature of scientific exploration. Ashley depicted medical science as a trusted discipline, but she was unable to connect her day-to-day life to any other field of science.

Carl Sagan once said, ‘Every kid starts out as a natural-born scientist, and we (society) beat it out of them’ (PT Staff, 1996) and based of my experience, I couldn’t agree more. Research suggests that teacher misconceptions about science can be linked to poor student attitudes towards science (Osborne et al, 2003; Gess Newsome, 2002; Davis & Smithey, 2009). Teacher interviews confirmed that they believe elementary students are enthusiastic and fascinated by opportunities related to science and scientific experiments. These responses suggest that science is exciting based on mixing things, seeing changes occur and the 'shock factor'. These responses are all product-based understandings of science with no acknowledgment to the process of a scientific thought.

The portrayal of science as entertainment masks the process of scientific discovery and instead replaces the malleable and changing world of science with a rigid product directed discipline. I would suggest that many people, regardless of their scientific background have attributed colour changes and explosions to what science is. However, science entails the process of hypothesizing, testing and observing. Visually appealing and stimulating experiments can enhance the scientific process, just not always within a short window of time. Students must absorb the entire process, a peek behind the curtain of these magic tricks.

As I began designing science summer camps and getting involved with outreach programs at schools, I was oblivious to this hindrance. I adopted a hooky magic trick from science advocate, Steve Spangler. The trick involved super absorbent polymers found in diapers. This crystalized substance could be used to solidify water in a cup. Suddenly, the old 'pick-a-cup' game became an exciting magic trick or lesson hook for students. I used this activity to 'shock' the students, but I failed to explain the process of designing the experiment. Teachers and students thought this 'science' was awesome because it was entertainment. In this instance, I unknowingly transmitted alternative perceptions of science.

People use the notion of scientific fact to support arguments with a belief that science provides undisputable evidence. The media and news sources share these alternative perceptions, and many of the people privileged with an appropriate understanding of scientific practice are professionally trained scientists (Schulz, 2014). Scientific tools and technology require appropriate practice with the skeptical eye. Understanding that science isn't only a set of facts or laws might allow teachers the creative and inquisitive nature to explore new ideas, better conditions and a lucid understanding of a complicated existence. That being said, I wonder to myself if the modern elementary school teacher, the 'jack of all trades', can be expected to assimilate to a scientific way of knowing or if the mental energy to do so would be too much to ask. This study conveys alternative perceptions that I believe may be transmitted to elementary school science students.

Finding 3: The Disconnect Between Inquiry-based Activities and Curriculum Goals

Teacher participants were unable to link inquiry-based activities to the expectations laid out in the New Brunswick science curriculum. The grade 3-5 science curriculum in New Brunswick contains three sets of outcomes. These outcomes are based on attitude, knowledge and skill (NBDEECD, 2002) and teachers are given autonomy to translate these outcomes in a variety of creative ways, but most participants didn't want this sort of flexibility. Ashley mentioned in her interview that she would prefer a scripted teaching companion. Ashley's request unknowingly contradicts the inquiry driven pedagogy expected of her to improve science instruction. This lack of agency to improve science instruction will be explored further in finding 4.

The inquiry mandate. In the past decade, elementary school teachers have been ushered towards using inquiry-based pedagogies, a style which teachers struggle to adopt (Luft, Bell & Gess-Newsome, 2008). Research supports inquiry-based science as a benefit to student content knowledge and attitudes (Flick & Lederman, 2006; Gess-Newsome, 2002; Lederman, 1999). The experience of working in science education with students and teachers has only strengthened my support of inquiry-based instruction, but teachers are not receiving equal opportunity to enhance their practice. Findings of this research suggest that teacher education and professional development aim to shift the elementary teachers' pedagogy rather than their epistemology. Teacher education with an epistemological approach would target the framework and purpose of scientific practice rather than the teaching strategies that best emphasize those practices.

Science is a tool for navigating through problems by using strategy and an open mind. Inquiry-based learning requires that students formulate questions while teachers facilitate the process to find possible solutions (Brand & Moore, 2011). Without experience using a scientific framework or mindset, teachers become lost in the process. If a math teacher was asked to teach their curriculum through a musical number, they better hope to have a musical background. If not the message, the mathematical concept, would be completely lost in a horrible musical chaos.

Any curriculum becomes easier to work with as one submerges themselves into the subject matter. Teachers can not all be experts in every discipline, but they deserve genuine exposure to the real purpose of the scientific process. There are many scientists working in our communities, studying at universities and most importantly parenting students in elementary schools across New Brunswick. Gloria utilized these resources based on her small town closely connected community. These connections improved her self-efficacy with teaching science and her ability to tackle the science curriculum with an inquiry-based pedagogy, but they didn't restructure her concept of the science.

Getting lost in the shuffle. Many teachers spend their entire education avoiding science. These same individuals are asked to adopt the scientific epistemology and engage in a seemingly chaotic environment, the world of inquiry-based learning. Many outsiders have explained to me that inquiry-based lessons can appear to be chaotic and uncontrolled based on the students' enhanced level engagement and hands-on activity. This may explain the challenge of classroom management identified through teacher surveys. This lack of discipline combined with a poor self-efficacy will often result in avoiding inquiry, science or both (Menon & Sadler, 2016; Posnanski, 2002).

My belief is that chaos can go one of two ways, focused or unfocused. When students are engaged in the learning process the chaos does not have to manufacture anxiety. This study and my experience working in elementary schools in New Brunswick leaves me to believe that retaining a quiet and orderly classroom supersedes any type of focused chaos in science education and limits student exposure to doing science.

Educating preservice and in-service teachers. Many complaints arose concerning teacher education programs. Gloria, Sam and Ashely completed teacher education during different eras, but all implied a lack of confidence in their science education training. I have first-hand experience completing the elementary science education course training required in New Brunswick. This was a single course with little to no focus on the practice of inquiry-based science and how it could be applied to the New Brunswick curriculum.

The preservice teachers who are uncomfortable with inquiry-based strategies will likely retreat to using traditional methods of instruction (Levitt, 2002). The inquiry mandate introduces a pressure to improve student experience, but these pressures often result in traditional practices that teachers believe may increase test scores (Pringle & Martin, 2005). Ashely and Sam indicated these circumstances during interviews. Ashley said she may resort to YouTube videos to better explain content to students. Meanwhile, out of distress, Sam adopted the strategies of a colleague.

Are there more opportunities to better prepare future elementary school teachers? And how do we improve the self-efficacy of in-service teachers who do not understand how to connect inquiry-based instruction to science curriculum outcomes? The obvious answer would be yes, but upon further analysis there is a deeper issue to address. Teachers may not be prepared to put in the time and effort to improve.

Finding 4: Lack of Agency to Improve Practice

More in-service professional development, or a heavier focus on preservice teachers' inquiry-based pedagogy may help improve teacher experiences with science education in New Brunswick, but the findings of this study suggest an impeding factor that limits these solutions. My participants were continuously yearning for the ‘quick fix’ to improve their science teaching instruction. Upon reflection on the expectations of my participants as well as my own relatively recent experiences attaining a B.Ed., I had an epiphany regarding the learning process occurring among the teachers in this study.

Why kits fail. The desire for a ‘quick fix’ solution brings me back to resource kits. I have been supporting elementary school teachers by providing unit kits packed with materials and lesson plans. Some kits even include how-to explanatory videos. Teachers love this resource and contact me each year to borrow a kit from the university. Until now I believed this was a great solution to the phenomena in question. However, the findings of this study have led me to believe that resource kits may hinder a teacher’s ability to learn how to use inquiry to empower students to use science as a tool to gain knowledge.

Resource kits don’t necessarily improve a teacher’s scientific perceptive. Instead these resources act more as a guide for teachers, similar to the 5E model (Bybee et al., 2006). Teachers enjoy these guiding tools, but in my experience, kits leave little room to empower students to direct their own learning as the inquiry-based approach requires.

Many interview responses praised science kits and other easy to use resources. Additionally, there is literature to suggest that kits do improve the willingness of elementary teachers to do science with their students (Sherman & MacDonald, 2007).

Resource kits seem to remove the responsibility for teachers to gain a better understanding of the material they are teaching to students. Sam called in a variety of outreach programs, but she was unable to improve her level of self-efficacy teaching the material herself. Ashely mentioned that her Intensive-French curriculum read out like a script and was easy to follow. She wished for the same type of resource in science, which troubled me. Science is a subject that requires one to go off-script at times and leave room for error, questioning and the unexpected (Lederman & Abell, 2014). This open-minded framework requires confidence and experience, which my participants did not seem to be gaining through the various professional development avenues they were pursuing. Perhaps these teachers were not empowered in a constructivist professional learning setting to become accountable and take ownership over their own development.

Kits and pre-planned lessons are often presented as a set of step-by-step directions similar to a cooking recipe. Though taking direction is often important throughout science education, scripted step-by-step science guides the teachers and students away from exploring, learning and the inquiry-based approach. Even when these kits are designed to promote hands-on, interactive learning, the teacher must have the capability to facilitate, shift course and empower students to explore their ideas.

Improving self-efficacy. Employing quick-fix methods to improve scientific teaching can be compared to putting a Band-Aid on infected wound. The wound needs to be treated with disinfectant, stitched and monitored for further infection. Thus, to improve elementary school science instruction, more care, monitoring and supports must be in place to motivate and equip teachers.

Sam spoke of an encounter with a co-worker who attended a rare professional development seminar on science. She told her colleague to bring her back a pamphlet or an outline to follow. Again, an example of participants seeking the quick-fix solution to improve their science teaching practices without the agency to do the research or gain the experience with real science. If kits, outreach and/or curriculum documents are not enough to improve the practices of teachers then what avenues could be explored?

Many scientific professionals and not-for-profit groups operate in the province of New Brunswick and look to get involved with schools. These groups offer professional development on inquiry-based learning, action-based learning, transformative teaching, project-based learning and other modern strategies that New Brunswick has been looking to implement in classrooms across the province. This study suggests that teachers may be expected to find these opportunities independently and arrange with administrators or district leads to gain approval to attend these workshops. Ashley, for example, was unsure of her professional learning options and hoped for 'leave time' to attend such opportunities, but it was left unclear if she ever asked for this approval.

Improving the self-efficacy of a teacher requires a socio-constructivist approach through transformative learning (Brand & Moore, 2011). I can attest to this through both my coursework in the UNB Master of Education program and through the workshops I have delivered to local teachers. The teacher participants often come out feeling more confident, but I am not convinced significant improvement is being made by these teachers regarding their awareness of science as a tool. These workshops should identify and target the alternative perceptions held by teachers and offer a more appropriate framework to teach science.

Recommendations

According to this study, elementary school teachers are challenged by alternative perceptions of science, low self-efficacy, a lack of resources and a general unpreparedness to use inquiry-based science instruction. Teachers need redirection from the scientific content knowledge of elementary school science and should be encouraged to teach through a scientific frame that emphasizes skills and science as it relates to people's real lives. I believe elementary teachers need a stronger awareness and experience with science; specifically, understanding that science is open-ended, always questioned, and more about process then content. Educational leaders in New Brunswick can benefit from observing educational shifts and success stories in provinces like British Columbia. BC introduced a curriculum reform framed through key competencies such as communication, social awareness and critical thinking (British Columbia, 2015). Thus, in the next section I detailed some mechanisms that may improve the chances that elementary teachers embrace teaching science and not resist it.

Peer mentoring and outreach partnerships. Any elementary teacher with a low self-efficacy in science instruction should be provided a science education mentorship or partnership. Three key factors should be identified to for this recommendation to find success;

1. Mentor Teachers: Individuals with a strong understanding of science and the process of inquiry-based learning should to be identified and celebrated.
2. Target Schools: Elementary schools lacking science mentor individuals should be identified and prioritized.
3. Outreach Partners: The existing pool of scientific community outreach professionals should be identified.

My suggestion to the department of education, science subject leads, and coordinators would be to identify outreach programs and pair them with schools and teachers who require the most support. Capable teachers will improve inquiry-based pedagogy independently, but teachers such as those in this study require support. Some elementary schools in New Brunswick may not employ peer-coaches of inquiry-based science. Schools lacking these individuals should be identified by school districts across New Brunswick and paired with existing outreach partners who visit schools annually to work with students in a variety of science related subjects. For example, if the coordinators of the Anglophone School District – West identified that New Maryland Elementary School did not employ a teacher with a strong self-efficacy in science education, that school should be paired with a group such as Let's Talk Science – UNB to improve the teachers' professional practices and student experiences.

Many of the not-for-profit and organizations visiting New Brunswick schools use experiential and/or inquiry-based activities. These organizations include, The Gaia Project, Ducks Unlimited Canada, Falls Brook Centre, Nature NB, Let's Talk Science UNB, Let's Talk Science UNB-SJ, Meduxkaeag River Institute, Canadian Rivers Institute', 'NB Wildlife Federation', 'Fundy Biosphere', and others. Many of these environmental science groups focus on sustainability and environmental preservation and receive government funding to deliver these educational outreach programs. However, as discussed in this study, teachers may use these opportunities to remove personal responsibility from teaching science. Community partners and teachers should deliver these programs through a team teaching effort as suggested in the Teacher-Scientist Partnership Model (Houseal, Abd-El-Khalick & Destefano, 2014; Falloon, 2013).

Currently, confident teachers like Gloria, who require less support, take advantage of these opportunities to enrich her students' experience. Meanwhile, Ashley, who has much less teaching experience and confidence, explored options to improve her students' experience, but seems unsure how to access these resources. Ashley would benefit from a mentorship with a more experienced teacher at her school or a community partnership.

Schools with mentor teachers need to improve the infrastructure to appropriately coach and address misconceptions that target teachers' possess. This process should primarily target new teachers and find mentorships or partnerships to align their understanding of science and the inquiry-based process.

The teacher education experiences. Many efforts to reform the pedagogical practices of teachers depend on changes to the teacher education process. Preservice teachers may appear more impressionable than in-service teachers and are often directed toward new methods of teaching and learning in science (Abd-El-Khalick, 2001; Sherman & MacDonald, 2007; Plourde, 2002). Possible improvments are based on interview responses and include further promotion of the inquiry-based approach, mandatory prerequisite science coursework at the undergraduate level, and strateiges to improve a cross-currciular currciulum.

Promoting the inquiry-based model. Current elementary science expectations focus on the foundations of science through an inquiry-based framework (NBDEECD, 2002). Teacher education programs in New Brunswick should continue to improve and model the inquiry-based learning process. Inquiry-based courses have been used to improve preservice teacher attitudes and self-efficacy in the classsroom (Bhattacharyya et al., 2009; Bergman, D., & Morphew, 2015; Plourde, 2002). Ashley actively engaged in inquiry-based experiments during her teacher education, but she was unable to translate her role as a student to the facilatator when she began in-service teaching. Ashley claimed that observing a “model” science lesson would be more helpful to improve her own inquiry-based approach.

Undergraduate pre-requisite coursework. Teacher education programs may consider avenues to improve self-efficacy of elementary science instruction. Research has suggested that content knoweldge may impede feelings of science instruction self-efficacy (Posnanski, 2002). To improve the self-efficacy of science teahcers, a mandatory university level science course could be required before beginning the teacher education programs. Science is commonly misunderstood in our society and the nature of science is strongly debated among porfessionals. Preservice teachers have been identified as particularly vulnerable to poor self-efficacy (Menon & Sadler, 2016) and may benefit from experiencing high-level science coursework before entering the classroom as a teacher.

Cross-curricular promotion. Teacher education programs should continue promoting cross-curricular practices and configure interdisciplinary collaborations for opportunities to conduct educational projects. Modern educational institutions operate through interdisciplinary practices which may generate creativity and freedom of expression. Art could be used to explore chemistry. Math could be used to support the understanding of our solar system. Students do not often associate social and artistic subjects to the sciences (National Research Council, 2012). Elementary level sciences offer an excellent opportunity to blend literacy, math, science, social studies, art, physical education, and music. This contradicts traditional methods and as discussed in this study, teachers need to be exposed to opportunities that cross the curriculum effectively and feel comfortable enough to work around the expected timetables teaching.

Professional development in science. The expectations of teachers' professional learning led me to a personal revelation during this study. The progressive research surrounding the way students learn does not always apply to professional development opportunities for the teachers intended to facilitate that learning. The inquiry mandate is based on research suggesting how people learn effectively through experience and active process (Brand & Moore, 2011; Kolb et al., 2014; Gilbert et al., 2014). People learn and develop concepts through a variety of different mediums and teachers could be offered many more opportunities to improve their teaching through consultative and facilitated professional learning than are currently available.

Can we offer professional development to display process-based science and how inquiry-based instruction synergizes with the scientific method? I believe we can, but a recent study suggests that 39% of teachers in New Brunswick experience one or two science education PD sessions every five years (Campbell, Osmond-Johnson, Faubert, Zeichner & Hobbs-Johnson, 2017). Campbell et al. (2017) suggest that one day workshops are perceived as the most effective form of PD for teachers in New Brunswick. In my opinion elementary teachers need this experience through full day workshops based in a socio-constructivist framework in which alternative perceptions are addressed along with self-efficacy concerns.

Conclusions

This study asked the question, **what challenges do elementary school teachers encounter when implementing inquiry-based instruction while teaching science in New Brunswick schools?**

The findings of this study revealed that teachers may have alternative perceptions of science, teachers struggle to make connections between inquiry-based science and the curriculum, and teachers lack the resources they believe are required to conduct inquiry-based science and teachers are hoping for a short-cut solution to improve their pedagogy. Elementary teachers are facing a variety of challenges teaching science, but there are many opportunities to support teachers and promote inquiry-based teaching. This study informs teachers, administrators, the department of education and parents of some of the challenges elementary teachers face teaching science and how they can work together to support teachers and improve the educational experiences of students.

Though the findings of this research are compelling, only three teachers were interviewed and they represent a tiny glimpse of the elementary teacher population. I was unable to target male participants in my survey or interview data collection. Participants were at times aware of my personal bias toward inquiry-based instruction and science unit kits due to the theme of the workshop involved in collecting survey data. This may have skewed some of the responses teachers shared with me, but surprisingly the findings have shifted my bias away from kit-based resources.

Elementary teachers in New Brunswick seem eager to improve the experiences of their students. The participants in this study were engaged and hopeful to become better science teachers, but the path to improvement was at times unclear. In the future, teachers such as my participants should have opportunities to address their alternative perceptions in a supportive socio-constructivist professional learning environment, find mentorships or partnerships within their community and continue to receive educational opportunities that enhance their science teaching experiences. This research could be continued to explore the potential and efficiency of these solutions.

Further research on the efficiency of resource kits would also offer value to this phenomenon.

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APPENDICES

Appendix A: Workshop Survey/Consent Sheet for survey participants

1. What was helpful today and why?
2. What would you like to see more of in the follow up session?
3. Do you use any inquiry based science activities similar to today?
4. What support would help increase your use of science inquiry based activities?
5. What is the biggest challenge to using science inquiry in your classroom?
6. What resources do you have and what do you need to teach inquiry based science lessons?
7. How often do you teach science per week. per month?
8. What time constraints are you facing in teaching science?
9. What forms of assessment do you most often use in science?
10. How confident are you about your science knowledge?
11. Have you taken any university level science courses?
12. Geoff is doing his M Ed. thesis on the use of inquiry-based science activities in elementary classrooms. Would you be willing to do an interview with him? If so, please write your name and the best way to contact you here:

Survey Responses and science notebooks may be used in Geoff's science education research project. Please sign below if you agree to submit your responses to be used in the research.

1. My participation in this project is voluntary. I understand that I will not be paid for my participation. I may withdraw and discontinue participation at any time without penalty. If I decline to participate or withdraw from the study, no one on my campus will be told.
2. The research project aims to identify challenges elementary school teachers face teaching thought the inquiry-based pedagogy.

3. I understand that the researcher will not identify me by name in any reports using information obtained from this survey, and that my confidentiality as a participant in this study will remain secure. Subsequent uses of records and data will be subject to standard data use policies which protect the anonymity of individuals and institutions.

5. This project has been reviewed by the Research Ethics Board of the University of New Brunswick and is on file as REB 2017-143. For research problems or questions regarding subjects, the REB may be contacted through Jeffrey Landine of the Faculty of Education and REB member. jlandine@unb.ca ; 453-4839

6. I have read and understand the explanation provided to me. I have had all my questions answered to my satisfaction, and I voluntarily agree to participate in this study.

7. I have been given a copy of this consent form.

______________________________	_________________________
My Signature	Date
______________________________	_________________________
My Printed Name	Signature of the Investigator

Appendix B**:** One on One Interview Questions

1. Do you remember experiencing any science classes as a student? What were they like?
2. During your teacher training in university did you experience inquiry-based learning? Take me through that experience.
3. Take me through the last science lesson you planned and how it was instructed.
4. Describe in detail the most effective science lesson you've ever been a part of as a teacher or student.
5. Tell me about the process of planning the class schedule and how science fits into the weeks schedule.
6. How do you describe your personal relationship to the scientific community?

Note: These questions were developed to reflect my literature review on the challenges of teaching science. I frame these questions with a phenomenological structure to explore the experiences these teachers

Appendix C: Email to the school district

UNB Geoff MacDonald

158 Pine St, Fredericton NB, macdonald.geoff@unb.ca

Nov 2017
Recipient Name

Fredericton NB

Dear administrative members of Anglophone West School District:

We are pleased to offer two free science workshops in the fall of 2017 for elementary school teachers of grades three, four and five. We will explore science kits created for these grade levels, provide a free lunch as well as materials and resources for teachers to bring back to their classrooms. Workshops will run from 9am to 3pm with a one-hour lunch break.

These science workshops will be part of research study by master's candidate, Geoff MacDonald with help from supervisor, Mark Hirschkorn. The research project focuses on the challenges elementary teachers face with inquiry-based science instruction. Teachers are not obligated to participate in the research study and may choose to participate in only the workshops without being a research participant.

Teachers who volunteer as participants may withdraw at any point and the identities of the teachers involved will not be revealed in the research. The data collected for this research will include short surveys and workshop notebooks. This data will be locked in my supervisor, Mark Hirschkorn's office and only be observed by myself and my supervisor. This data will contribute to a document that hopes to develop a better understanding of the challenges teachers face with inquiry-based science instruction.

This project has been reviewed by the Research Ethics Board of the University of New Brunswick and is on file as REB 2017-143.

More about the research:

Currently there is a priority in elementary science education toward using more inquiry-based forms of instruction during the periods in which teachers want their students to learn science (Gess-Newsome, 2002;Flick & Lederman, 2006;Friedrichsen, Van Driel & Abell, 2011;Branch, N. B., 2002). However, in addition to this priority is some consensus in the literature regarding how resistant to adopting inquiry-based science strategies elementary teachers are, and even the ones that do, have immense difficulty with the process.

My research is intended to explore how New Brunswick elementary teachers implement inquiry-based forms of science instruction, what challenges they face when seeking to do so, and what sorts of supports can be provided for them in their teaching. In short to document and help them bridge the gap between the theories of what they are being told is inquiry-based science instruction and what they do with their students in their classes. My research question asks: **What challenges do elementary school teachers encounter implementing inquiry-based instruction while teaching science in New Brunswick schools?**

Teachers can register for the workshops by emailing me at my email address listed above. The two days will be different and teachers are welcome to register for either day or both. Each day will explore a variety of science activities.

Looking forward to working with you this fall.

Regards,

Appendix D: Consent letter for one-on-one interviews

UNB

Consent for Participation in Interview Research

I volunteer to participate in a research project conducted by Geoff MacDonald from the University of New Brunswick. I understand that the project is designed to gather information about teachers experiences with inquiry-based science. I will be one of 3-5 people being interviewed for this research.

1. My participation in this project is voluntary. I understand that I will not be paid for my participation. I may withdraw and discontinue participation at any time without penalty. If I decline to participate or withdraw from the study, no one on my campus will be told.
2. If I feel uncomfortable in any way during the interview session, I have the right to decline to answer any question or to end the interview.
3. The interview will last approximately 45 minutes. Notes will be written during the interview. A digital audio recording of the interview and subsequent dialogue will be made. If I don't want to be recorded, I will not be able to participate in the study.
4. I understand that the researcher will not identify me by name in any reports using information obtained from this interview, and that my confidentiality as a participant in this study will remain secure. Subsequent uses of records and data will be subject to standard data use policies which protect the anonymity of individuals and institutions.

5. This project has been reviewed by the Research Ethics Board of the University of New Brunswick and is on file as REB 2017-143. For research problems or questions regarding subjects, the REB may be contacted through Dr Jeff Landine of the Faculty of Education and REB member. jlandine@unb.ca

6. I have read and understand the explanation provided to me. I have had all my questions answered to my satisfaction, and I voluntarily agree to participate in this study.

7. I have been given a copy of this consent form.

___________________________	_______________________
My Signature	Date
___________________________	_______________________
My Printed Name	Signature of the Investigator

For further information, please contact:
Geoff MacDonald
macdonald.geoff@unb.ca
506 261 0247

Curriculum Vitae

Candidate's full name:

Geoffrey MacDonald

Universities attended (with dates and degrees obtained):

University of New Brunswick, Fredericton NB	B.Ed.	2013
University of New Brunswick, Fredericton NB	B.Sc. Biology	2011

Publications: none

Conference Presentations: none