The Influence of Research Experience on Science Teachers’ Practice

By

Andrea Carvalho

A research paper submitted in conformity with the requirements
For the degree of Master of Teaching
Department of Curriculum, Teaching and Learning
Ontario Institute for Studies in Education of the University of Toronto

Copyright by Andrea Carvalho, April 2017
Abstract

Despite definite benefits to using an inquiry-based approach to science education, some teachers are finding it difficult to implement inquiry elements beyond the basic concepts, especially scientific investigation skills (SIS). This study investigates how a sample of high school science teachers with graduate degrees in science draw from their previous research experience to teach scientific inquiry skills in the classroom. It was found that having research experience allows these teachers to be more knowledgeable and authentic in their classes, as well as place a high value on student mastery of scientific investigation skills. These findings imply that ensuring that having experience conducting their own scientific investigations either through their science education, teacher education, or professional development likely encourages teachers to value teaching SIS.

Key Words: science teachers, scientific investigation skills, research experience
Table of Contents

Abstract 2

1. Introduction 6
   1.1 Research Context 6
   1.2 Research Problem 7
   1.3 Purpose of Study 7
   1.4 Research Questions 8
   1.5 Background of Researcher 8
   1.6 Overview 9

2. Literature Review 10
   2.0 Introduction 10
   2.1 Approaches to Science Education 10
      2.1.1 Traditional approaches to science teaching 10
      2.1.2 Student experiences of inquiry-based science education 11
   2.2 Teacher Factors Affecting Student Achievement 13
      2.2.1 Education level of teachers 13
      2.2.2 Teachers’ science research experience 14
   2.3 Barriers to Teaching Inquiry in the Science Classroom 15
      2.3.1 Cultural barriers 15
      2.3.2 Technical barriers 17
      2.3.3 Political barriers 17
   2.4 Conclusion 18

3. Research Methodology 19
3.0 Introduction 19
3.1 Research Approach and Procedures 19
3.2 Instruments of Data Collection 20
3.3 Participants 21
   3.3.1 Sampling criteria 21
   3.3.2 Sampling procedures and recruitment 22
   3.3.3 Participant bios 22
3.4 Data Analysis 23
3.5 Ethical Review Procedures 23
3.6 Methodological Limitations and Strengths 24
3.7 Conclusion 25

4. Research Findings 26
4.0 Introduction 26
4.1 Research Experience Supported Teaching Practice 27
   4.1.1 Content knowledge 27
   4.1.2 SIS knowledge 28
4.2 Sharing Experience with Students 29
   4.2.1 Added authenticity 29
   4.2.2 Sharing experiences with SIS 31
4.3 Overcoming Challenges to Teaching SIS 32
   4.3.1 Technical 33
   4.3.2 Cultural 34
4.4 Supports for Teaching SIS 36
5. Conclusion

5.0 Introduction

5.1 Overview of Key Findings and their Significance

5.2 Implications

5.2.1 Broad implications: The educational community

5.2.2 Narrow implications: My professional identity and practice

5.3 Recommendations

5.4 Areas for Future Research

5.5 Concluding Comments

References

Appendix A: Letter of Consent

Appendix B: Interview Guide
Chapter One: Introduction

1.1 Research Context

Canadian elementary and secondary science curricula have undergone a conceptual shift from being focused on teaching facts to fostering scientific literacy as defined in the Common Framework of Science Learning Outcomes (Council of Ministers of Education [CMEC], 1997). CMEC defines scientific literacy as a “combination of the science-related attitudes, skills, and knowledge students need to develop inquiry, problem solving and decision making abilities to become life-long learners, and to maintain a sense of wonder about the world around them” (p. 4). The goals of science education here are doubly to prepare students for post-secondary education and careers in the fields of science and technology, and to promote informed and responsible participation in society.

The Ontario Ministry of Education ([OME], 2008) states that its goals are for students: “to relate science to technology, society, and the environment; to develop the skills, strategies, and habits of mind required for scientific inquiry; to understand the basic concepts of science” (p. 4). The Ontario curriculum is well aligned with the Canadian Framework, and additionally, it places a great emphasis on promoting scientific investigation skills as a basis for promoting scientific literacy (CMEC, 1997).

The terms inquiry-based instruction, scientific investigation, constructivist learning, and discovery learning, among others, refer to activities where students construct knowledge through investigations that they have themselves designed (OME, 2008). For the purpose of this study, inquiry-based instruction will include teaching strategies that foster students skills of scientific investigation as defined by the Ontario curriculum.
1.2 Research Problem

Despite definite benefits to using an inquiry-based approach to science education, research (Chowdhary et al., 2014; Roehrig & Kruse, 2005) suggests that some teachers are finding it difficult to implement curriculum elements beyond the basic concepts, especially scientific investigation skills. Time constraints and lack of classroom resources, among other issues, are cited as barriers to teaching scientific investigation skills (Anderson, 2002; Kubicek, 2015). However, a more teacher-related barrier is teachers’ lack of first hand experience with scientific inquiry outside of the classroom (Chowdhary et al., 2014; Kubicek, 2015; Wallace & Kang, 2004). Hearing directly from teachers who have first hand experience conducting scientific investigations may point to some additional barriers to teaching scientific investigation skills as well as ways that teachers can develop their own skills.

1.3 Purpose of Study

The purpose of this study is to explore how Ontario secondary science teachers with graduate degrees and resulting research experience use their hands-on science background to inform their teaching practice. Secondary science teachers are particularly relevant because they are more likely to be teaching content that is directly related to their field of research than are elementary teachers (Tigchelaar, Vermunt, & Brouwer, 2012).

In this study I explore this topic by interviewing a sample of teachers about: the scientific investigation experience they gained before teaching; their perceptions of how their experience informs their practice in terms of the inquiry skills and teaching strategies they employ; and the degree to which they seek ongoing scientific professional development.
I hope my study will provide with suggestions for helping teachers create a greater alignment between the lab and the classroom. I hope it can also inform science teacher education on areas of growth in inquiry-based education.

1.4 Research Questions

The primary research question in this study is: How is a sample of Ontario secondary science teachers with graduate degrees in science reportedly using their research background to inform their teaching of scientific investigation skills? Sub questions to further guide the study are: how do these teachers prioritize the curriculum elements regarding scientific investigation skills; how has research experience have been transferable in teaching scientific investigation skills; and what initiatives do these teachers take to stay current in both the fields of science and education?

1.5 Background of the Researcher

The relationship between teachers as scientists and scientists as teachers is interesting to me. Although their audiences differ, both are in the business of gathering and sharing knowledge. Many people view scientists as an elite group far removed from their own lives. If we define a scientist as someone who studies or has expert knowledge in a field of science, this should include our science teachers. I think that if science teachers were more assertive about portraying themselves as scientists, it would humanize students’ perceptions of who scientists are and facilitate their learning of what scientists do. As a high school and undergraduate student I remember the most well respected teachers and professors were the ones that often shared their research experiences with us. They made it clear to their students that they were experts in their fields.
During my undergrad I worked as a teaching assistant for first and second year biology classes. I was surprised at the variety of experiences my first year students had. Some were very confident using lab equipment, however, others had never used a microscope before. This inspired me to question what kinds of experiences high school students had with laboratory skills and by extension scientific investigation skills, and what caused them to be so different.

1.6 Overview

To respond to the research questions I will be conducting a qualitative research study using purposeful sampling to interview Ontario secondary science teachers with graduate degrees and resulting research experience, about their use of previous research experience in their teaching practice. In Chapter Two, I review the literature on the place of scientific inquiry in the curriculum, and factors that determine how teachers implement it. Next, in Chapter Three, I elaborate on the research design. In Chapter Four I report my research findings and discuss their significance in light of the existing research literature, and in Chapter Five I identify the implications of the research findings for my own teacher identity and practice, and for the educational research community more broadly. I also articulate a series of questions raised by the research findings, and point to areas for future research.
Chapter Two: Literature Review

2.0 Introduction

In this chapter I review the literature in the areas of science teaching strategies, and how they are implemented. More specifically, I review factors that influence how scientific inquiry skills are being taught and how this varies among teachers. I start by reviewing literature around traditional and inquiry based methods within science education. Next, I review kinds of teacher beliefs that are pertinent to their teaching practice. Finally, I conclude with barriers teachers face in using inquiry-based teaching strategies.

2.1 Approaches to Science Education

Two kinds of teaching methods are generally employed in science classes. Many are familiar with traditional teaching methods, which are based on explicit instruction. Alternately, inquiry-based instruction gives students the opportunity to construct knowledge. Both methods can be beneficial to students as outlined in this section.

2.1.1 Traditional approaches to science teaching

Despite various calls to reform science education, the traditional style of teaching science is widely prevalent in elementary to university level classes. It is generally a teacher-centred approach, where the teacher is the main source of knowledge and instructional content (Furtak et al., 2012). Teachers favouring this approach may rely on lectures and textbook readings, as well as laboratory activities where students must follow an explicit procedure, colloquially called ‘cookbook labs’ (Furtak et al., 2012). Here the assessment of students’ understanding is based on their ability to remember facts or follow problem-solving steps. While studies (Cakiroglu, Capa-Aydin & Hoy, 2012; Furtak et al. 2012) have evidence in support of inquiry-based teaching strategies, many teachers adhere to the traditional approach. Since many teachers tend to teach
using strategies that they preferred as students, if they benefitted from traditional teaching methods, these teachers will favour the same methods in their own practice (Eick & Reed, 2002).

Kirschner, Sweller, & Clark (2006) have shown that this method is still valuable and that learners do need at least some explicit instruction when being taught novel information or skills. Students are also found to be less prone to misconceptions when taught by direct instruction (Kirschner, Sweller, & Clark, 2006). There are other definite advantages to traditional teaching strategies. It is time effective, as well as cost effective, especially for large classes to have lecture-based instruction (Brown et al., 2006). This approach to teaching is also thought to be more efficient for covering a wide range of content (Brown et al., 2006). In a study contrasting students in an inquiry lab with a traditional ‘cookbook’ lab, the traditional class was found to be more confident in their ability to read and understand biology facts and experimental procedures since they had more experience at those tasks than the inquiry class (Gormally et al., 2009). They also had higher confidence in their abilities although this is likely because their experiments ‘worked’ as long as they followed the given procedure correctly (Gormally et al., 2009).

2.1.2 Student experiences of inquiry-based science education

Canadian science curricula are in the midst of a reform. It had been proposed that science education must move from largely “canonical science knowledge that is removed from the lives of students” (Darby-Hobbs, 2013, p. 78) to giving students a set of tools and skills that they can use to solve problems using a scientific worldview (CMEC, 1997). Curriculum documents encourage teachers to move from traditional teaching methods based on direct instruction, to using more inquiry or application based methods of teaching science in order to foster scientific literacy.

Scientific inquiry and investigation skills include all those necessary to carry out
scientific investigations as well as understand how scientists acquire knowledge (Kubicek, 2015). These skills are categorized as initiating and planning, performing and recording, analyzing and interpreting, and communication and teamwork, according to both the Pan Canadian Framework (CMEC, 1997) and Ontario Science Curriculum (OME, 2008). Skills within these categories include identifying problems, formulating hypotheses, developing plans, making observations, gathering data, safely using materials and equipment, problem solving, and forming and justifying conclusions based on evidence, among others (OME, 2008). There are many lists of skills outlined within the literature and there is much overlap between them. For example, Trowbridge, Bybee, & Powell (2004) includes skills of acquisition, organization, creativity, manipulation and communication and the National Science Teachers Association (2004) includes asking questions, designing investigations, using appropriate equipment, drawing conclusions, and communicating results.

Inquiry-based science education is generally perceived as beneficial for students’ learning. Studies have found that contrasted against more passive forms of learning such as lectures, reading, or ‘cookbook’ type laboratory activities, classes where inquiry-based labs took place generally promote a deeper understanding of concepts (Anderson, 2002; Gormally et al., 2009). Furthermore, students in inquiry-based classes were better able to transfer their knowledge to new situations (Gormally et al., 2009). Lord and Orkwiszewski (2006) found that college students in inquiry-based courses were more motivated to find meaningful solutions to problems, while students in traditionally taught classes were more motivated to complete their tasks quickly.

Increased confidence, self-efficacy, and independence have been noted in some groups of students (Saunders-Stewart, Gyles & Shore, 2012) although, Gormally et al. (2009) noticed that the students doing ‘cookbook’ type labs were more confident in their abilities because the
structured experiments led them to experience failure less often than students in inquiry based labs.

Inquiry-based instruction has been found to support student achievement with some specific populations. Scruggs et al. (1993) found this approach to be highly effective for secondary students with learning disabilities. It was also found to positively affect students’ achievement in urban schools (Songer, Lee & Kam, 2002). Inquiry-based science education has been correlated with increases in academic achievement in students who are traditionally underserved by the passive acquisition of knowledge, for example, students that have trouble learning from textbooks and lectures (White & Frederiksen, 1998). Some older quantitative studies have found slightly negative or inconclusive correlations between inquiry-based class time and student achievement (Jackman et al., 1987; Pavelich & Abraham, 1979). However, drawing comparisons between studies is difficult as not all studies were on the same kinds of inquiry activities or used the same measures of student achievement.

There is a place for both traditional and inquiry based science education in today’s classrooms.

2.2 Teacher Factors Affecting Student Achievement

Students’ experience and achievement levels in science education depend on a numerous factors, including characteristics of their teachers. Teachers’ level of education and experience with scientific investigation skills are two areas that will be explored in this section.

2.2.1 Education level of teachers

As a general indicator of teacher education relating to student achievement, Monk (1994) found the number of university courses in a subject area a teacher took to be correlated with student achievement. However, it was also found that gross indicators of education such as
number of degrees were not correlated with student achievement (Monk, 1994). Another study of science teachers teaching courses inside their field of study versus other science courses found that even when teachers had excellent pedagogical knowledge, they had difficulty planning for and teaching lessons for courses outside of their field (Sanders, Borko, & Lockard, 1993). In science courses outside of their field, the teachers used less student-driven teaching strategies and more lecture and seatwork based teaching (Sanders, Borko, & Lockard, 1993). When science teachers have high content knowledge, they are also more likely to be aware of students’ misconceptions about the topic. This leads to students having a better understanding of topics that their teacher has high content knowledge in (Sadler et al., 2013). This is significant because when majoring in science in university, the range of topics studied is often narrower than what is covered in high school science classes.

2.2.2 Teachers’ science research experience

Research suggests that teachers’ use of inquiry activities in the classroom may be predicted by their own experiences with science research, that is, university or professional experiences (Windschitl, 2002). Windschitl (2002) suggests that teacher education should provide the opportunity for science teacher candidates to conduct their own scientific investigations rather than only learning about scientific investigations. In this study of teacher candidates, all participants realized that it is difficult for students to create testable questions; this is mirrored by the fact that very few teachers have ever developed such questions during their own schooling (Windschitl, 2002). Eick and Reed (2002) give cases of teachers using their own schooling experiences to inform their teaching. Teachers who viewed themselves as “hands-on learners” taught using many hands-on or inquiry based activities. Teachers who had little hands-
on experience with science as students viewed themselves as “traditional learners” and relied on traditional teaching methods.

In light of this, Chowdhary et al. (2014) suggest that even after experiencing scientific research based professional development, factors such as teacher belief’s about student abilities, and beliefs about the necessity of investigation skills may also limit teachers’ motivation to teach scientific investigation skills.

2.3 Barriers to Teaching Inquiry in the Science Classroom

Despite the championing of inquiry-based science education, there are barriers preventing many teachers from regularly implementing it in the classroom. Three categories of barriers have been identified and used throughout literature: cultural, political, and technical (Anderson, 1996).

2.3.1 Cultural barriers

Cultural barriers include internal factors affecting the teacher, that is, their beliefs and perceptions of the value of inquiry based science, their own teaching efficacy, and their students’ abilities. Studies have found that if teachers hold the belief that inquiry is not valuable (Czerniak & Lumpe, 1996) or if they have low efficacy beliefs (Enochs & Riggs, 1990), they are less likely to incorporate scientific inquiry skills into their teaching practice. Qualitative studies (Eick & Reed, 2002; Czerniak & Lumpe, 1996) of elementary and secondary teachers have shown that teacher beliefs about the usefulness of inquiry-based science tend to be based on their past experiences. These experiences can include school and work. However, it was noted that their beliefs are more influenced by their experiences in science classes as students rather than from teacher education (Eick & Reed, 2002). In other words, if they had positive inquiry experiences as students they were more likely to believe that inquiry-based science was useful.
Another cultural barrier is the belief that the textbook should be the main source of information (Anderson, 2002; Johnson, 2007). This was found to be a significant barrier to teaching scientific inquiry skills for new teachers and teachers teaching outside of their usual subject area, who rely on the textbook to guide them through instructional content (Roehrig & Kruse, 2005). Pressure to prepare students for the next grade level or for standardized testing has also been found to cause teachers to focus on direct instruction rather than spending time on inquiry-based activities (Anderson & Helms, 2001). Some teachers have reported the belief that labs are expendable relative to teaching core concepts and therefore prioritize direct instruction (Wallace & Kang, 2004). In one study (Czerniak & Lumpe, 1996), up to 80% of teachers surveyed did not believe that inquiry-based teaching strategies were necessary, and 74% used these strategies less than once a week. These teachers felt that covering knowledge-based curriculum content was their priority while inquiry activities were ‘extra.’

Teachers’ beliefs about their students also affect the ways they use inquiry in the classroom. For example, if a teacher believes that their students do not have the conceptual knowledge, problem-solving skills, or maturity level necessary to complete inquiry-based laboratory activities safely or in a timely manner, they may do experiments as a demonstration done by the teacher or not do them at all (Wallace & Kang, 2004).

Barriers based on teachers’ beliefs can be overcome through exposure to and experience with inquiry-based teaching methods (Eick & Reed, 2002). Other researchers suggest collaboration with successful colleagues and opportunities for professional development can generate an appreciation for inquiry-based teaching (Johnson, 2007).
2.3.2 Technical barriers

Technical barriers are a result of the abilities of teachers and students. Although there may be overlap, students and teachers’ abilities are not always aligned with their efficacy beliefs.

Technical barriers for science teachers include lack of skill in instruction, content, or classroom management (Johnson, 2007). These are challenges often faced by new teachers and teachers who do not have an academic background in the course content (Johnson, 2007). Science teachers who do not have strong content knowledge often rely on the course textbook for information, and find it challenging to create inquiry-based activities (Davis, Petish, & Smithey, 2006). Classroom management issues may compromise safety and time, making it difficult for teachers to plan inquiry activities that students can complete with minimal guidance (Wallace & Kang, 2004).

Resolution of technical barriers is similar to that of cultural barriers. Johnson (2007) found that they can be resolved by gaining teaching experience, professional development in the subject area, and collaboration with experienced colleagues.

2.3.3 Political barriers

Political barriers are those that are outside of teachers’ control. They include support from administration, colleagues, and parents, school resources, and opportunities for professional development. For example, crowded classrooms and shortened periods in a growing school hindered some teachers’ ability to do group activities with their classes because it was difficult to move around and interact with all students (Johnson, 2007). When the school’s budget is a constraint, the kinds of laboratory activities available are limited. This can prevent students from gaining experience using various equipment and materials associated with scientific investigations (Roehrig & Luft, 2004). Pressure from other stakeholders such as parents,
administrators, or colleagues can be a barrier if they are under the belief that the traditional teaching methods, which they are most familiar with, are best for students (Anderson, 2002). Political barriers may also be responsible for increased stress levels when science teachers feel the need to provide their own resources for their class, or give up lunch breaks to collaborate with colleagues because administration has not allocated the time or funding (Johnson, 2007).

Johnson (2007) found that political barriers are easiest to overcome in the absence of other types of barriers. The quality of inquiry-based instruction only significantly decreased when science teachers experienced political barriers in addition to other cultural or technical barriers (Johnson, 2007).

2.4 Conclusion

In this literature review I looked into research on science literacy and science teaching methods, how teacher beliefs affect their practice, and barriers teachers face to using inquiry based teaching methods. There are clear benefits to both inquiry-based and traditional teaching models and are both necessary to facilitating learning in the classroom. Despite this fact, as well as governmental support for inquiry-based science teaching, it is not always easy for teachers to implement. The more experience teachers have using scientific inquiry, the more competent they are at teaching it. In light of this the purpose of my research is to learn how having graduate education in the sciences and thus research experience affects the ways teachers teach inquiry and investigation skills in the classroom.
Chapter Three: Research Methodology

3.0 Introduction

In this chapter I describe the research methodology of my study. I begin by reviewing the general approach, procedures, and data collection instruments before elaborating on participant sampling and recruitment strategies. I explain my data analysis procedures and review the ethical considerations relevant to my study. I identify a range of strengths and limitations of the methodology. Finally, I conclude with a brief summary of key methodological decisions given the research purpose and questions.

3.1 Research Approach and Procedures

This research study has been conducted using a qualitative research approach involving a review of the literature surrounding my topic and semi-structured interviews with practicing teachers. Historically, qualitative research has been criticized for its lack of generalizable results and reproducibility (Harwell, 2004). These qualities are necessary for quantitative research when studying causal determination or relationships among variables (Creswell, 2002). However, qualitative research is a valuable way of delving deeply into people’s personal experiences in ways that may or may not be predictive of others’ experiences (Johnson & Onwuegbuzie, 2004). Qualitative research aims to explore meaning and interpret phenomena from the perspective of the participant (Harwell, 2004). It also allows for one to collect data that is defined in the participants’ own terms rather than terms imposed by the researcher (Johnson & Onwuegbuzie, 2004). Seeking a reproducible, objective truth is not the aim here. Instead qualitative research acknowledges the influence of context, including the perspective of the researcher on the participant and accepts that different results may be obtained from the same study if done by a different researcher, or at a different time (Harwell, 2004).
My study investigates how a sample of teachers draws from their previous research experience to teach scientific inquiry skills in the classroom. I acknowledge that these teachers’ experiences will not be representative of all teachers’ experiences. Qualitative methods lend themselves to this topic, as my goal is to explore the personal experiences of a particular sample of teachers, rather than discover an objective truth.

3.2 Instruments of Data Collection

Within qualitative research, data is typically collected through observations, interviews, document analysis, audio-visual material analysis, or a combination (Creswell, 2002). This study uses semi-structured interviews to collect data. Semi-structured interviews allow for a combination of open ended and close-ended responses from participants (Creswell, 2002). Close-ended questions ask participants for either a brief response, or to select a response from a predetermined set of options, such as ratings on a scale (Gay, Mills, & Airasian, 2012). This allows information to be gathered efficiently and responses can be compared across participants. Open-ended questions allow the participants to create their own responses. Semi-structured interviews are advantageous because participants can give detailed, elaborate responses that the researcher may or may not be able to anticipate, unlike structured interviews which are limited to close-ended responses predicted by the researcher (Gay, Mills, & Airasian, 2012).

My interviews were conducted in a one-on-one and face-to-face setting. This allowed the interview to remain confidential and for the participant to feel more comfortable speaking about personal experiences (DiCicco-Bloom & Crabtree, 2006). Face-to-face interviews also allow for non-verbal information to be conveyed such as tone and body language, which would otherwise be lost through online correspondence (DiCicco-Bloom & Crabtree, 2006).
My interviews follow a protocol (Appendix B) which inquires into three areas in order to address my research questions:

1) Academic background,

2) Experiences teaching scientific investigation skills, and

3) Professional development

3.3 Participants

Here I review the sampling criteria I established for participant recruitment, outline my recruitment procedures, and introduce the participants. I also describe my methodological decisions for choosing my sampling criteria and recruitment procedures.

3.3.1 Sampling criteria

The following criteria was used to select teacher participants:

1) Teachers will have taught one or more science classes at the secondary level.

2) Teachers will have one or more graduate degrees in the sciences.

3) Teachers will have scientific investigation experience in a laboratory setting.

4) Teachers will be employed within the Greater Toronto Area.

The study is limited to high school science teachers because the courses they teach are more likely to be relevant to their research background. The Ontario Science Curriculum describes scientific investigation skills as necessary to scientists (OME, 2008). Graduate education in the sciences includes designing and carrying out a scientific investigation. Teachers with this education level will have used the skills outlined in the curriculum first hand. Due to convenience and maintaining geographical consistency, teachers from the Greater Toronto Area were recruited.
3.3.2 Sampling procedures and recruitment

Within qualitative research non-random sampling is employed in order to recruit participants that are best suited to helping the researcher to understand a phenomenon (Creswell, 2002). Non-random sampling strategies include, convenience sampling where people readily available are recruited, purposive sampling where criteria of interest are specified and then the researcher locates participants who fit that criteria, and snowball sampling where each participant suggests other potential participants (Johnson & Christensen, 2000).

I primarily used convenience and purposive sampling where I contacted science teachers at schools I have encountered through academic and professional experience, provided a description of my research and sampling criteria and asked them to distribute my contact information to teachers in their departments. Providing my contact information rather than asking for that of teachers ensures that any participants who contact me to participate are volunteering willingly rather than feeling obliged to participate (Desposato, 2015).

Non-random sampling limits the generalizability of research, as the participants are less likely to be diverse enough to be representative of an entire population (Johnson & Christensen, 2000). My study was tailored to teachers with a particular set of experiences; so random sampling would not be an efficient recruitment technique. Based on my intention of exploring personal experiences rather than generating generalizable trends, these sampling methods were sufficient to find a small group of participants that fit the sampling criteria.

3.3.3 Participant bios

Christina has taught in Toronto for 6 years. At the time of our interview she was teaching Grade 9 and 10 Science, however she has had experience teaching senior Biology, Chemistry, and Physics as well. She completed high school and her Bachelor of Science in
biochemistry outside of Ontario. She completed her Master of Science and teacher education in Ontario.

Britney has taught in Toronto for 8 years. At the time of our interview she was teaching Grade 9 Science and Grade 12 Biology. She usually teaches Grade 9 or 10 Science and Grade 11 or 12 Biology. She completed her Bachelor of Science in human biology and she began her Masters of Science after she had already started her teaching career.

3.4 Data Analysis

In order to complete data analysis, first all interview transcripts were transcribed. Each transcript was read individually and codes were identified. Codes are used to describe segments of text that relate to a topic (Creswell, 2002). Inductive coding was applied, where codes were developed as they appeared in the transcript (Johnson & Christensen, 2000). Co-occurring codes share the same meaning, or describe two related concepts (Johnson & Christensen, 2000). Next, codes were synthesized into major themes. These themes were analyzed based on their significance in relation to the existing literature around the topic of teaching scientific inquiry skills.

3.5 Ethical Review Procedures

In any study, ethical concerns may arise in relation to the rights of the participant, the research site, and the honest reporting of research (Creswell, 2002).

Respecting the rights of the participant includes gaining informed consent and giving them the ability to withdraw from the study at any time. Before taking part in the interviews, participants were given information regarding the purpose and aims of the study as well as the use of the results. They signed a consent letter, authorizing the interview to be audio recorded. Privacy and anonymity are also rights of the participant. Individuals participating in any study
should expect that their privacy would be respected (Lichtman, 2013). Pseudonyms have been assigned to each participant and identifying information regarding schools or students has been excluded from the interview transcripts. Confidentiality must also be prioritized (Lichtman, 2013). Research data including interview transcripts were stored on a password-protected device and will be destroyed after five years.

Regarding the research sites, interviews were conducted in locations and times agreed upon by myself and the participant, where we were both permitted access and caused no inconvenience to others (Lichtman, 2013).

In order to report the research thoroughly and honestly, feelings of coercion on the part of the participant were minimized. The recruitment methods ensured that participation was entirely voluntary. Rapport between the researcher and participant can affect the quality of data collected in interviews (Creswell, 2002). Due to the professional relationship between the participants and researcher, that is, experienced teachers and a teacher candidate, it is unlikely that the participants experienced the researcher as having power over them (Lichtman, 2013).

3.6 Methodological Limitations and Strengths

The most significant limitation to this study is the lack of generalizability due to the small sample size. As mentioned previously, generalizability is not necessarily the purpose of qualitative research (Johnson & Onwuegbuzie, 2004). Another limitation is that the sample does not include a control group. I inquired into the experiences of teachers with graduate degrees as they teach scientific inquiry skills. However, the experiences of teachers without graduate degrees as they teach scientific inquiry skills were not accounted for. This is not a comparative study so comparing the experiences of the two groups is not the aim. Response bias in the participants’ answers is another possible limitation of this study (Lichtman, 2013). This is the
phenomenon where the participants consciously or subconsciously give answers that they think the interviewer wants to hear. One more limitation of qualitative research is the potential for the researcher’s biases, assumptions or values to affect the interpretation of data. In order to minimize both of these limitations it was important for the researcher to be aware of how they were perceived by the participants and to reflexively position themselves in relation to the study (Creswell, 2002).

A strength of qualitative research is the increased credibility or internal validity of the research. This refers to the accuracy of the researcher’s interpretation of the data collected from the participants. Interviews allowed for participants to explain their answers in their own terms and ensure that the researcher collects data that fully captures their experiences.

3.7 Conclusion

In this chapter I described my research methodology. I started by outlining my qualitative research approach, explained how it differs from quantitative research, and highlighted the strengths of it to my study. I described my instruments of data collection as semi structured interviews, which allowed me to gather robust data from my participants. I described purposeful, convenience sampling as my main method of participant recruitment. My sampling criteria and an introduction to each of my participants is also included. I then described my methods for analyzing my data in terms of generating codes and themes from the interview transcripts, and outlined ethical considerations involved in this research, that include respect for the participant, site, and honest reporting of findings. Finally, I discussed some limitations as well as strengths associated with qualitative research. In the next chapter I will report the findings of my research.
Chapter Four: Research Findings

4.0 Introduction

This chapter elaborates on the findings around my central research question of how teachers with graduate degrees in the sciences and resulting laboratory experience are reportedly using that research experience to inform their teaching of scientific investigation skills, as well as the sub questions: how do these teachers prioritize the curriculum elements regarding scientific investigation skills; how has research experience have been transferable in teaching scientific investigation skills; and what initiatives do these teachers take to stay current in both the fields of science and education?

In Chapter Two a review of the literature around the teaching of Scientific Inquiry Skills (SIS) was discussed. Qualitative and quantitative studies on the effectiveness of inquiry-based teaching, teacher factors that affect student achievement, and barriers to using inquiry-based teaching methods were reviewed. In Chapter Three my research methodology via interviews with teachers was described. Semi-structured interviews with two high school science teachers with Master of Science degrees were conducted and the interview transcripts were coded and analyzed. This chapter explores the themes that emerged from an analysis of the research interviews conducted. The themes are organized into the following sections: 1) Research experience supporting teaching practice, 2) Teachers were able to share experiences, 3) Challenges to teaching SIS, and 4) Supports to teaching SIS. Each theme will be discussed below and supported by participants’ responses as well as the established literature. The next chapter will outline implications and recommendations for the educational community based on these findings.
4.1 Research Experience Supported Teaching Practice

Considering my central research question, “How is a sample of Ontario secondary science teachers with graduate degrees in science reportedly using their research background to inform their teaching of scientific investigation skills” I found two ways in which these teachers believe their research experience in laboratory settings supported their teaching of curriculum content. Both teachers believe their content knowledge and knowledge of SIS is strengthened by their experiences.

4.1.1 Content knowledge

Both participants believed that their Masters degree in biology allowed them to gain further content knowledge, with which they were reportedly able to strengthen their teaching. Both participants had conducted research in biology and felt they were better able to understand and explain topics in various biology units because if it. When describing curriculum units related to her Masters research, Britney stated that,

[before that, metabolism was just sort of like, I don't know, just a memorization based unit. And I think I maybe breathed a bit more life into it since I’ve been able to explain some of my work. I’ll explain these are experiments you can do, how you know if something’s wrong. And because I was in an exercise lab, a lot of students enjoy that part, that’s exercise based.

She acknowledged that going back to complete a Masters after having started her teaching career was beneficial to her content knowledge in a number of areas in biology especially the metabolism unit in Grade 12 Biology. My other participant Christina also felt that she was able to make connections from her research on metabolic pathways to the Grade 12 unit on metabolism, among others. This aligns with Sanders, Borko, and Lockard’s (1993) finding that
teachers are most confident in teaching the areas they specialized in, however specialization in one area does not correlate with overall teaching ability. In addition to feeling more confident with concepts, both teachers also felt confident with their knowledge of scientific investigation skills.

4.1.2 SIS knowledge

Having research experience also reportedly supported both participants’ understanding of scientific investigation skills, especially skills needed to design an investigation. In a study of science teachers’ investigative experiences Windschitl (2002) found that beginning teachers who did not have experience carrying out their own research encountered challenges in teaching this skill to students. Supporting this statement, my participants who did have professional research experience felt confident in teaching skills such as formulating hypotheses, controlling variables, analyzing data, and communicating findings, skills that had been required during their Masters. When asked about how working in a lab helped her teaching, Britney stated that, “[h]aving an intimate familiarity with what these techniques actually do and how you get let’s say a positive result versus a negative result, you know, controlling for your study, things like that. It comes up in so many different areas. For sure, having that experience in the lab is great.” Her experiences with performing laboratory tasks as well as interpreting data have reportedly been useful in many areas in her science classes. Having a Masters degree and associated research experience reportedly allowed these teachers to have specialized content knowledge in certain areas and practical familiarity with scientific investigation skills. In addition to this knowledge, both participants also valued the experience they gained from graduate school that they were able to share with their students.
4.2 Sharing Experience with Students

This theme is centered on the ways having research experience supported my participants beyond what is outlined in the curriculum. In addition to supporting content and SIS knowledge these teachers felt that they could strengthen students’ understanding of what scientists do by adding authenticity in the form of real life context to their lessons, as well as advise students who might be interested in following a similar career path.

4.2.1 Added authenticity

Both teachers felt that they were able to add authenticity; give more context, or real life applications, to their teaching of curriculum content and scientific investigation skills. Christina emphasized that she was able to not only teach how to design experiments but also explain why each step is important to scientists. In reference to lab report writing, she reported that,

[t]he journal writing was helpful because you start to understand the whole point of it.

Why are we even learning how to write a lab report?… When you’re doing research you need to know how to do procedures and you can’t reinvent those every time you need to run a gel…When I wrote journals and my thesis itself I had to put the model number of the centrifuge. You have to be crazy specific because people need to know if its not working, why?

In addition to Christina describing the necessity of some of the more tedious parts of science communication, both participants also spoke about sharing with students some of the ways the experiments done in high school are different from conducting your own experiment in a lab. A big difference is that in school, experiments are designed to always give good results, while in real research perfect results are rare. Christina exemplifies this when she describes explaining this difference to her students:
I try to talk about [experiments] in terms of research because, as you know, it never works! Like when we do a lab with the kids it works every single time because we’ve tested it and we know it will work but it’s good to have them understand how important it is to repeat and repeat because you need to prove that it worked and wasn't just a one time thing or a statistical anomaly and that it’s actually true evidence.

Christina believed it important that students understand how school labs are different from other kinds of scientific experiments. Britney also shares experience from her research with her classes in order to prevent students from getting discouraged when things don’t work out perfectly in the lab,

I try to tell them that there’s nothing wrong with getting wrong answers, that’s the norm, I mean in the lab 90% of your work is going to fail and it’s that one tenth that you’re lucky enough that you can get successful to publish. So I really try to convince them not to doctor their data.

She uses her knowledge of scientific research to reassure her students that they have not failed when they don’t get the exact results they expected during labs.

Both teachers drew from personal experience to compare scientific investigations done at the high school level to their own research experience. This reflects Gormally et al’s (2009) study of inquiry-based learning in science classes, which suggests that activities where students design their own investigations can bridge this gap in conceptualizations of how research is carried out. This would mean that students at the high school level would experience some of the challenges of collecting data that supports a hypothesis at an earlier age. Both my participants reportedly aim to give their students this experience. They support their students’ understanding of how research is carried out by sharing personal anecdotes. One drawback to this is the limited
time available in high school classes for students who are unable to get working results from an experiment, as Christina says; “you don't have a billion years to repeat the same thing over and over again you know.”

4.2.2 Sharing experiences with SIS

Both participants valued being able to share how skills they are teaching have been helpful in their own research experience. Christina spoke of the excitement of discovering new things and answering big questions: “[Students should] realize how cool things are. That's what science is founded on. Not balancing equations, not whatever, rearranging formulas. Those are good skills, they will make you a good scientist one day. But that's not what the whole point is.” She reported sharing with her students how doing your own research requires skills taught in high school but is also more exciting than that. When sharing personal experiences with research Britney, though, received mixed reactions from her students. She first said that her students were engaged in her stories because she worked in an exercise lab, so the students were interested in the studies of athletes. Other students were surprised to hear about the working conditions:

I think they find [the research] impressive. And it’s good to know how disciplined you have to be if you want to pursue a career in science…Like you’re passionate about it, and you spend sometimes 12 to 20 hours a day in a lab and that's not uncommon, and they think that's ridiculous! They think that you should get paid for publications and for your hours, and you don’t… And so they seem to think that scientists are crazy.

She believes that while students think the research itself is interesting, they may not be mature enough to understand that research scientists are not solely motivated by financial gain the way people might be in other careers. She added that, “I think that’s a maturity thing. You have to complete your undergrad and know what you’re passionate about and see. …getting that value of
hard work, I think it takes a while to understand.” Despite this disconnect, she values being able to advise students who are interested in pursuing science at the post secondary level when she says, “But hopefully it’s drawing a few students, where they realize, like some students do have that work ethic, they really want to work and I can at least explain to them a little bit about what it would be like.” Gormally et al. (2009) found that having students participate in inquiry-based learning help can students to understand why and how scientific investigations are carried out. Reports from my participants suggests that another way to have students understand why and how scientific research is done is by interacting with someone with that experience. I suggest that having an experienced teacher to mentor students and dispel misconceptions of what scientists do and help students become more informed about how scientific research is done.

Both participants valued having a wealth of experiences they were able to share with their students. Despite these benefits, teaching SIS also came with challenges.

4.3 Overcoming Challenges to Teaching SIS

Teaching SIS can be challenging; however, having research experience may emphasize the importance of these skills, motivating my participants to continue to focus on it in their teaching practice. In this context, challenges refer to factors that the participants have identified as making teaching SIS difficult. This differs from barriers as described in Chapter Two, which prevent teachers from teaching SIS. Challenges described by my participants fit into the cultural and technical categories described as barriers in Chapter Two. One interesting note is that neither teacher addressed political challenges when it came to teaching inquiry. There were no reported issues of lack of funding or support from administration or other stakeholders. In Johnson’s (2007) study of teachers’ attempts to implements more inquiry based science practices, it was found that challenges to teaching SIS, political barriers were the easiest to overcome, especially
in the absence of other challenges. This is reflected in the data collected from my participants. Insight into the challenges around teaching SIS and how they are overcome allows us to explore how teachers prioritize the SIS curriculum elements.

4.3.1 Technical

Technical challenges are a result of the abilities of teachers or students. These are factors based on teachers’ and students’ abilities which make teaching SIS difficult. Both participants described inquiry-based teaching, and teaching SIS as energy intensive, both while teaching and while assessing students. Britney described supervising students planning labs as follows: [While students are working] you constantly need to be on your feet. It’s energy intensive for sure. You have to go from group to group to group making sure they’re on task, you don’t want to give them too much guidance and not too little at the same time because they need to investigate on their own…

Supervising students as they complete independent work can be physically tiring. Christina spoke about the time and effort it takes to create and transport solutions for chemistry labs, “if you have three preps, which is a huge reality unless you're at a big school like this one, then it gets challenging. You don't have time to make solutions and clean solution bottles every day.” Having multiple classes to prepare for, or having classes spread out around a school made preparing labs difficult. Neither teacher however, reported being discouraged by the energy intensiveness and continued to incorporate inquiry skills and SIS in their teaching practice because their own research experience may have caused them to place a high value on it.

Johnson (2007) had mentioned that technical challenges are often resolved through gaining experience with teaching, and collaboration with colleagues. Both of my participants
indeed had these supports in place, as discussed in the following section on supports, further allowing them to persist.

4.3.2 Cultural

Cultural barriers include those related to the beliefs of the teachers. These are factors that make teaching SIS difficult, or less of a priority, that are due to the beliefs of the teacher. Wallace and Kang’s (2004) study of high school teachers found that many believed inquiry learning to be only supplemental to the basic concepts outlined in the curriculum. In contrast, my participants seemed confident in the balance they had struck between using direct instruction and teaching SIS based on the needs of their students. Britney described choosing inquiry-based and hands-on activities as follows: “they are time consuming so you have to be selective with what are really effective and what are really developing the skills that they need to be successful in science.” Her university experience may have informed her that practical labs as well as content knowledge are evaluated at the post-secondary level, and that students would need to be prepared for both in order to be successful.

When discussing how she prioritizes curriculum basic concepts versus investigation skills, Christina said that, “time is a huge constraint! Like it can be and it doesn’t have to be. It’s funny every now and then I’ll consult the curriculum documents to be like ‘Am I doing what I’m supposed to be doing here?’ And honestly sometimes I think we go way overboard!” By going ‘overboard’ she means she used to focus on teaching a lot of information, more so than was required by the curriculum, which took away from time that could have been spent on SIS. Christina also described teaching a group of students who were likely not going to continue with science courses in the following grade, “…if the priority for a group of kids that maybe aren’t going forward is to say ‘Hey lets get some investigation skills,’ then we could reprioritize our
time and we wouldn't have to focus so much on overwhelming content.” Their passion for scientific investigation may have also inspired these teachers to want to share it with students. White and Frederiksen’s (1998) finding that inquiry-based learning can be beneficial for students who are underserved in traditional science classes. Christina’s use of inquiry activities as a strategy to engage students reflects this finding.

Cultural challenges also include students’ efficacy beliefs; their beliefs about their own abilities. Teaching SIS requires some maturity on the part of students. Britney felt that it is challenging to get students to design their own investigations and feel confident in their results. She said that,

[t]hey’re afraid of original ideas. They want to make sure that someone else has the same result or online there’s something. I don’t know, there are challenges with it. Students are afraid to make mistakes and there’s nothing wrong with that. I think that takes a bit of maturity to realize.

She also described student-led inquiry activities as another area that relies on students being mature. She said that, “I find [student-led activities] are really challenging if it’s self-directed at all, students need to be disciplined enough to stay on task.” This attitude from students reflects Gormally et al’s (2009) finding that students were less confident when doing inquiry-based activities because they were focused on getting correct results. Sharing her own experiences with frustrating results was a strategy Britney used to encourage students to persevere. Classroom culture and the dynamic between students was a factor my participants considered when choosing what teaching strategies she would employ.

Overall, challenges addressed by my participants included time and effort involved in running labs, how they prioritized curriculum elements, and students’ efficacy beliefs. While
these factors made teaching investigation skills challenging, neither teacher admitted that any of these factors limited or decreased their efforts to incorporate SIS and mentioned some of the ways they were able to overcome them. Having experience using the scientific investigation skills they were teaching might have confirmed to these teachers that they were useful and important enough to teach despite being challenging.

4.4 Supports for Teaching SIS

Supports for teaching scientific investigation skills include factors that either help teachers overcome barriers described in the previous section, or which teachers employ in order to improve their own practice. Through my data analysis I found that having research experience may have supported teacher’s ability to scaffold investigation skills and motivated them to seek out professional development opportunities.

4.4.1 Long-term scaffolding

Both participants agreed that learning how to apply SIS is a long and slow process for students. Adjusting one’s expectations for students is a way to account for this. Teaching SIS with the goal of students mastering each skill is difficult to achieve. Christina acknowledges that the investigation skills needed to complete her Masters research took her entire academic career to accumulate. She thinks of the accumulation of SIS as a very gradual process and calls for teachers to collaborate and focus on a few skills at each grade level with the goal of students being able to successfully design their own investigation by Grade 12:

Let’s say I taught the same kids for 2 or 3 years in a row then sure maybe you could be like “Ok listen we’ve really tackled those skills and at this point that should be a basic skill” and it would be really nice if department-wise we could collaborate and say in grade 9 the only goal of the lab report is to get the kids to know how to ask questions-
questions that define measurable and independent variables, and how to state a hypothesis. We do it all at once and just expect their skills at all of it to get better when maybe it would be better to think about it as one skill at a time. So maybe in grade 10 they can take that question and hypothesis and start designing a procedure based on it.

Christina said this process is not yet in place in her school, however she tries to focus on and assess only a few skills at a time when doing inquiry-based activities in her classes. Britney combats this challenge by scaffolding the way she assigns lab reports. She described how,

for the first lab… it’s informal. So usually I would help them create the hypothesis, write the purpose. Observations are pretty straightforward. I’d give them examples of what would be a good one versus a poor one. And it wouldn't be until the second lab that we do analysis and conclusions.

As we can see here, both teachers use scaffolding or a gradual release approach to teaching SIS. This reportedly helps their students become proficient at the various skills since they only focus on a few at a time; rather than teaching lab report writing all at once and having students be only mediocre at each part. This kind of teaching strategy as a support for teachers aligns with Johnson’s (2007) statement that barriers to teaching SIS can be resolved through gaining teaching experience and acquiring pedagogical content knowledge. Having an acute awareness of how challenging it can be to design and report on scientific investigations helped my participant developed this strategy as they gained experience and became more familiar with how students learn best.

4.4.2 Taking initiative about professional development

My participants discussed a number of professional development resources. In this section, professional development resources include any materials or methods used by teachers
in order to acquire or learn new content or strategies for teaching SIS. Both participants maintained a keen interest in new developments in science. They both reported looking to mainstream science news sources for content that could be incorporated into their classes. When asked how she keeps up to date in science, Christina says that, “I don't subscribe to journals or get Google alerts on publications but I definitely get Scientific American, Nature Magazine, things like that. I listen to podcasts.” Britney also cites Internet searches as her primary way of finding new content, labs, or teaching strategies. She also stated that she keeps up with educational research by enrolling in additional qualification courses annually. NTIP’s teacher mentorship program and helpful textbooks are also resources discussed in prior sections. A commonality between all the resources described is that these are all things the teachers had to seek out on their own, rather than resources provided through teacher education or school administration, or other external stakeholders. My participants continued to use the investigative skills they refined through their academic careers to improve their teaching practice. This is in alignment with the findings of Chowdhary et al.'s (2014) study of the effect of professional development on science teachers’ practices. They found that the more teachers took initiative and fully committed to participating in professional development experiences, the more likely they were to work towards improving their practice.

Both of my participants considered their Masters degrees a form of professional development, and continued to seek out other form of growth as teachers and scientists throughout their careers. The teachers expressed that despite the challenges associated with teaching SIS, scaffolding instruction and seeking out professional development were strategies that allowed them to continuously strengthen their teaching practice.
4.5 Conclusion

Through exploring the ways these teachers reportedly used SIS in the classroom, we can see that having hands-on research experience was valuable to them. Both participants prided themselves in their ability to share authentic experiences with using the particular skills they were teaching. They were able to give more contexts to why skills such as writing accurate procedures and reports or analyzing data are valuable and necessary to scientists. Challenges the teachers experienced when teaching SIS were described and well reflected the literature outlined in Chapter Two. Finally, factors or actions, which supported these teachers ability to teach SIS in addition to their own experience, were described. It was found that learning from other teachers, and accepting that learning SIS is a gradual process for students were very important to my participants.

Not all teachers have had the opportunity to conduct their own research through graduate education or otherwise, however in Chapter Five, I will discuss the implications of these findings for science educators with and without research experience as well as potential areas for future research.
Chapter Five: Conclusion

5.0 Introduction

This chapter outlines implications of the research findings on how having experience carrying out ones’ own scientific investigations through laboratory experience, can support the teaching of scientific investigation skills. I discuss implications for both the educational community as well as my own teaching practice. Next, I suggest recommendations for educators and teacher educators based on my findings. Finally, I outline areas for future research based on this study in light of the extant literature.

5.1 Overview of Key Findings and their Significance

Chapter Four contains responses to my central research question, “how is a sample of Ontario secondary science teachers with graduate degrees in science reportedly using their research background to inform their teaching of scientific investigation skills?” It was found that having research experience supported these teachers’ content knowledge on the curriculum topics related to their Masters degrees, supported their knowledge of how to use scientific investigation skills, and allowed them to present these skills authentically to their students. Additionally, their lab experiences caused these teachers to value and understand the necessity of SIS, which may have allowed them to persist in teaching SIS despite the challenges of it. Finally, it was found that possibly because of this high value placed on SIS, these teachers are also enthusiastic about seeking out professional development that helps them to continuously get better at it. The teachers interviewed in this study as well as the literature reviewed in Chapter Two tell us that having research experience can give students a better idea of what scientists do and why. These findings are significant because they give insight into practices, such as the
sharing of experiences, that help students to have a better understanding of the nature and applications of science.

5.2 Implications

Implications for both the educational community and my personal practice will be discussed in this section. Based on the reported experiences of the teachers interviewed in this study, having experience working in a laboratory setting and conducting their own investigation was significant to their teaching practice. I discuss what these findings imply about teacher skill sets and student experiences for high school science teachers, with and without research experience. Broad implications include those for science teachers, students, and administrators, while narrow implications will outline the effect of this study on my personal teaching practice.

5.2.1 Broad: The educational community

This research study suggests that for the participants interviewed, having a research background has allowed them to add authenticity to their science classes by giving context to the skills that they are teaching. The Ontario Science Curriculum has a focus on building scientific literacy and scientific investigation skills for students, so teachers who have first hand experience with these skills may be better equipped to teach it. Teachers with this experience have the opportunity to make the practice of science more authentic to students. They may also be better role models or advisors for students who are interested in the sciences. They can give realistic guidance to students who are interested in pursuing a career in science in the future. Students may hold stereotypes of the demographic features of who scientists are, so having more teachers portraying themselves as scientists may help to dismantle these misconceptions.

Teachers without practical experience designing and carrying out investigations may have more difficulty portraying authenticity or real life context to the scientific investigation
skills they are teaching. This has the potential to leave students with misconceptions about what scientists do or what to expect out of post secondary education or careers in science. This study found that having an appreciation for SIS may have caused the teachers to be more resilient in the face of challenges to teaching SIS. This implies that teachers without this experience may be more likely to focus on basic concepts rather than teaching SIS.

Additionally, having more science teachers with graduate education may inspire greater trust from parents and the public in their children’s science education. However, if hiring science teachers with graduate education were to be prioritized, this may decrease diversity in the field since a smaller proportion of people have the resources to pursue a Master of Science before entering teaching. This may have the adverse effect of making science teachers less relatable to students and decreasing the diversity of individuals in science that students are exposed to.

5.2.2 Narrow: My professional identity and practice

This study has emphasized to me how important it is to make science relevant for students. Teachers must be able to give real world context for the content they teach. I realize this is especially important when teaching scientific investigation skills which otherwise may seem too esoteric for students to see how they can be useful. I aim to be eager to share my own research and science-based work experiences with my own students. I hope that this can contribute to making science-based careers seem more achievable to my students. In addition I want to take the advice of my participants and continue to learn throughout my career through seeking out new knowledge, and taking initiative to participate in professional development. I also realize that the balance between teaching content and SIS depends very much on the group of students I am teaching and what their learning goals are in my science class. Adjusting this balance based on the needs of a class can be a way to keep students engaged. Focusing on SIS
can be a way to build scientific literacy for students who may not continue to pursue science after my class. A focus on SIS, especially the practical skills and use of equipment, may also be necessary in order to prepare students for post secondary education as well as the workplace.

The findings of this research have made me to reflect on what will inspire me to continue to teach skills and access new resources even when it is challenging to do so. I feel that reflecting on how the content I teach has been helpful to me or to others will be a way to stay motivated to get students engaged with it.

5.3 Recommendations

Limiting hiring practices at the school or school board level to favour science teachers with graduate education would likely create a less diverse pool of science teachers; thus I recommend making experiences of carrying out one’s own scientific investigation more accessible to teachers. This can be done in a few ways. Within teacher education programs, pre-service teachers should have an investigative experience as part of their science-curriculum education in order to gain an authentic appreciation for the skills that they will be teaching. For practicing teachers, administrators should provide professional development workshops focused on scientific investigation skills. Since both participants reported that having a Master’s degree supported their content knowledge in the related curriculum area, these investigative experiences should be available across a number of science topics in order to promote mastery across the curriculum.

Both participants in this study cited colleagues as a resource for learning new teaching strategies. They valued the sharing of resources and materials within their departments as well as formal mentorship opportunities. Based on this finding teachers should be allotted more time for collaboration, mentorship, and observation of colleagues’ teaching. This can be done at the
school level through allocated time on professional development days or, in Ontario, through the Ministry of Education by increasing the mentoring component of the New Teacher Induction Program.

5.4 Areas for Future Research

This study calls for more research on how teachers’ education and experience affect students’ experience in science classes. While both participants spoke of factors that have supported their teaching, quantitative research correlating a teacher experience factor with a student experience factor would be necessary to confirm their effectiveness. Teacher factors could include general education level, education level in the same subject area as the courses they teach, or participation in a teacher mentorship program. These could be correlated with students’ grades, standardized test scores, or surveys on their attitudes towards science or science classes.

While this study focuses on teachers with research experience through graduate education, a similar research question could be asked about science teachers who have had practical experience through working in science-based professions. How do those teachers use their experiences to influence their teaching of scientific investigation skills? Unless their career was as a scientist, the job skills necessary may not exactly match SIS in the Ontario curriculum, however I imagine they would be able to bring similar authenticity and context to some of the science content. This type of research, correlating teacher experiences with student achievement, could be used to inform teacher education programs on what kinds of experiences teacher candidates need before entering the field. It could also inform school administrators when making hiring decisions or planning professional development activities.
5.5 Concluding Comments

Overall this study provides insight into a group of teachers that has not been well represented in the extant educational literature. This study informs us that teachers with graduate education have been able to add authenticity and personal anecdotes to support their teaching of SIS, and that their experience with SIS may have caused them to put a high priority on teaching these skills well. I hope that the experiences shared by my participants encourage other science teachers to find ways to share the importance of scientific investigation skills in their classrooms. Regardless of what experiences they have teachers need to reflect on why these skills are important to them, and to use that to inform the way they prioritize them. By doing this, teachers can make science and science education seem more accessible and more attainable to their students.
References


Academics, 23(1), 5–31.


Appendix A: Informed Consent Letter

My name is Andrea Carvalho and I am a student in the Master of Teaching program at the Ontario Institute for Studies in Education at the University of Toronto (OISE/UT). A component of this degree program involves conducting a small-scale qualitative research study. My research focuses on how secondary science teachers support students in developing scientific investigation skills. I am interested in interviewing teachers who have obtained a graduate degree in science and have first hand experience applying scientific investigation skills in the lab. I think that your knowledge and experience will provide insights into this topic.

Your participation in this research will involve one approximately 60 minute interview, which will be transcribed and audio-recorded. I would be grateful if you would allow me to interview you at a place and time convenient for you. The contents of this interview will be used for my research project, which will include a final paper, as well as informal presentations to my classmates. I may also present my research findings via conference presentations and/or through publication. You will be assigned a pseudonym to maintain your anonymity and I will not use your name or any other content that might identify you in my written work, oral presentations, or publications. This information will remain confidential. Any information that identifies your school or students will also be excluded. The interview data will be stored on my password-protected computer and the only person who will have access to the research data will be my course instructor Angela Macdonald-Vemic. You are free to change your mind about your participation at any time, and to withdraw even after you have consented to participate. You may also choose to decline to answer any specific question during the interview. I will destroy the audio recording after the paper has been presented and/or published, which may take up to a maximum of five years after the data has been collected. There are no known risks to participation, and I will share a copy of the transcript with you shortly after the interview to ensure accuracy.

Please sign this consent form, if you agree to be interviewed. The second copy is for your records. I am very grateful for your participation.

Sincerely,

Andrea Carvalho

MT Program Contact:
Dr. Angela Macdonald-Vemic
Consent Form

I acknowledge that the topic of this interview has been explained to me and that any questions that I have asked have been answered to my satisfaction. I understand that I can withdraw from this research study at any time without penalty.

I have read the letter provided to me by Andrea Carvalho and agree to participate in an interview for the purposes described. I agree to have the interview audio-recorded.

Signature: __________________________________

Name (printed): _____________________________

Date: ______________________________________
Appendix B: Interview Guide

I’m working on a project about inquiry skills in science education. The aim of my research is to explore how teachers with a research background are transferring that experience into their classroom teaching. This interview should take about 1 hour. It is divided into three sections; your academic background, experiences with scientific investigation skills in the classroom, and professional development. I want to remind you that you can choose not to answer any question, and you are free to withdraw from participation at any time. Do you have any questions before we start?

*Turn on recorder*

To begin can you state your name for the recording?

Turn off, replay to check for audio quality, turn back on.

**A. Background:**

1) How long have you been working as a teacher?
2) Which grades and subjects are you currently teaching? Which have you taught in the past?
3) Tell me about your academic background?
4) Can you elaborate on what research you did during your MSc?
5) Did your MSc research relate to any strands in the curricula you currently teach?
   Yes → Do you share your experiences when you teach that unit?
   No → Do you tell your students about it anyway?
6) How do they respond?/ Are students interested?

**B. Teaching Scientific Investigation Skills:**

I’ll now ask you some questions about the classes you are currently teaching

7) How often do you focus on Scientific Investigation Skills in class?
8) Do you teach it as a separate unit, tied into other units, both?
9) Can you tell me about a lesson where you taught students Scientific Investigation Skills?
   Prompts: was it successful? Why/why not? How was learning assessed?
10) How do you assess the Scientific Investigation Skills part of the curriculum ie curriculum Strand A or the I in KICA?
   Prompts: labs, homework assignments, projects, etc
11) How do students usually respond to [methods from Q6]?
Prompts: do they enjoy it, find it challenging etc

12) What are some challenging things about teaching scientific investigation/inquiry skills?

Prompts: eg time constraint, student ability/ behaviour

13) Do you feel more prepared to teach inquiry due to your own research experience?/ Do you think it would be harder to teach if you didn’t have research experience already?

Yes → In what ways?
No → Why not?

14) Did you find any skills you learned in grad school to be transferable in teaching? Explain.

Yes → In what ways?
No → Why not?

15) Do you try to stay current with your field of research?

Yes → In what ways? Is it challenging?
No → Why not?

16) How important do you believe it is to explicitly teach scientific investigation skills?

Does it differ between grades or streams?

17) At the end of a course, what are some things (skills, knowledge) you hope students remember?

C. Professional Development:

18) We talked about research preparing you to teach scientific investigation skills. Did you feel that teachers college adequately prepared you to teach it as well?

19) Do you seek out professional development opportunities for teaching science?

Yes → What kinds?
No → Why not?

20) Are you aware of any supports that are available to address some of the challenges to teaching SIS you mentioned earlier?

Prompt with reminders.

21) Can you share some advice for new teachers on teaching inquiry skills?

Turn off recorder.
That concludes our interview. Thank you for your time and for sharing your experiences. Do you have any questions for me?