The Impact of STEM Outreach Programs in Addressing Teacher Efficacy and Broader Issues in STEM Education

by

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A thesis submitted in conformity with the requirements for the degree of Master of Arts
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Abstract

This study explores the potential of the Outreach Workshops in STEM (OWS) to affect Science, Technology, Engineering, and Mathematics (STEM) teachers’ content knowledge, self-efficacy, and pedagogical approaches, as well as its viability as a potential form of professional development (PD). The data for the thesis is taken from a larger longitudinal study looking at the potential of OWS to influence middle school students’ and teachers’ attitudes and beliefs around STEM. The study employs a mixed-methods design, utilizing surveys, open-ended questions, interviews, and observations. The findings show that there were no significant changes in teachers’ content knowledge, confidence, or pedagogical approaches. However, the majority of participants reported that they learned new teaching ideas and considered the workshops to be an effective PD opportunity.
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Chapter 1: Introduction

Skills in science, technology, engineering, and mathematics (STEM) are considered key to greater innovation, productivity, and improved standards of living (Council of Canadian Academies, 2015). Consequently, STEM education is viewed as necessary for preparing students for the 21st century; so that they can compete in the future economy (Howard-Brown & Martinez, 2012) as well as fully participate in modern society (American Association for the Advancement of Science [AAAS], 1990; Marrero, Gunning, & Germain-Williams, 2014). This notion is encompassed in the idea of STEM literacy, whereby individuals come to understand STEM knowledge in light of how it impacts their personal and social lives as well as the world as a whole (Bybee, 2010).

STEM education is therefore a prominent driving-force behind many educational reforms (Howard-Brown & Martinez, 2012). It is a rethinking of the conventional approach to teaching science, math, technology, and engineering, in that it integrates these four subjects into one “meta-discipline”. STEM reforms call for more student-centered, hands-on interactive instructional methods (DeCoito, 2014; Fioriello, 2010). Ultimately, the reforms aim to i) increase STEM understanding and literacy for all, and ii) promote enrollment in postsecondary studies leading to STEM occupations (DeCoito, 2014; Mishagina, 2012; National Research Council [NRC], 2013). Unfortunately, for the most part STEM education is “business as casual”; neither integrating these disciplines nor offering improved, alternative pedagogical approaches (Sanders, 2009). Furthermore, there appears to be confusion about the precise nature and implementation of STEM in many school settings (Marrero et al., 2014).

There are several concerns regarding STEM education. They include insufficient teacher preparation, and low self-efficacy for teaching STEM. Many science and mathematics teachers require greater preparation in STEM content knowledge and skills, which is further hindering
the successful application of STEM educational practices (NRC, 2010). Additionally, teachers’ self-efficacy and beliefs about teaching and learning STEM significantly impact whether or not better pedagogies are employed effectively (Davis, Petish & Smithey, 2006). Self-efficacy is “the belief in one’s capabilities to organize and execute the courses of action required to manage prospective situations” (Bandura, 1995, p. 2). According to the self-efficacy theoretical construct, a greater sense of self-efficacy will push a teacher to work longer and harder, even when faced with notable constraints. This is due to the teachers’ increased beliefs in their own abilities in terms of effective pedagogy, as well as in their students’ abilities to learn this material (Woolfolk et al., 2009). Teachers with lower self-efficacy, often as a result of insufficient content knowledge, tend to rely on expert sources of knowledge and forego student-centered teaching (Yoon, Pedretti, Bencze, Hewitt, Perris, & Van Oostveen, 2006).

Effective pedagogy for integrated STEM education is student-centered. Such pedagogy is expected to increase students’ retention and promote problem solving and higher-level thinking skills (Stohlmann, Moore & Roehrig, 2012). However, these benefits are only possible if educators are actively enacting the inquiry-based pedagogical approaches (NRC, 1996). Because traditional didactic teaching continues to dominate science and math classrooms, pre- and in-service teacher education has been undergoing a reformation process in order to evolve traditional science and mathematics instruction into what is needed for STEM education (NRC, 2010).

Outreach programs are one possibility for students to experience hands-on, inquiry-based instruction. Such programs have become widely recognized for introducing students to STEM options, careers, and degree programs while also increasing their knowledge of scientific inquiry and the nature of science (Nadelson & Callahan, 2011; Rahm, Martel-Reny, & Moore, 2005). Outreach that goes beyond the ‘regular’ and/or ‘traditional’ science or math class can
offer connections to real-world applications and teach additional skills to both students and teachers (Thomasian, 2011). It has been found that teachers also enjoy actively participating in outreach workshops (Kelter, Hughes, & Murphy, 1992). The workshops are often effective in modeling inquiry-based, hands-on instruction, a necessary component of STEM education (DeCoito, 2015; Fioriello, 2010). The outreach workshop approach is one that students enjoy and from which teachers can learn. The hope is that teachers can learn to improve their STEM instructional practices and, as a result, incorporate more hands-on, inquiry-based teaching. Because STEM outreach programs can be as instructive and informative for teachers as for their students, it is worth exploring the program’s potential to influence teacher development.

1.1 Scope, Context and Purpose of the Study

This thesis analyzes teacher data accumulated over a three year STEM longitudinal project. Four key STEM stakeholders, namely, an industrial firm, an outreach provider, a university, and a school board, formed a partnership to execute this project. The aim of the long term study, of which this thesis is a part, is to aid the outreach program providers to better comprehend the influences of their strategies on STEM learning in the intermediate division specifically. Ultimately, the goal is to measure any impacts on long-term educational outcomes for K-12 students and teachers in relation to STEM education. In the case of students, the goal is to promote students’ interest in and awareness of future studies and possibly careers in STEM fields. As for teachers, the goal is to improve STEM teaching, STEM career awareness, technology integration, and 21st century learning practices. My thesis employs a mixed-methods design, utilizing the teacher data to focus on whether the STEM outreach workshops can affect teachers’ STEM instruction, STEM content knowledge, and self-efficacy in teaching STEM.

The outreach provider, Outreach Workshops in STEM (OWS) is a Canadian not for profit organization that delivers STEM outreach programs to K-8 students. Since its
establishment in 1989, the program has served over six million students. OWS currently operates in Ontario and Alberta with occasional presentations in other provinces. The organization is dedicated to sparking children’s interest and love of science, technology, and the environment through hands-on inquiry. Their mission is to ignite scientific wonder in children through investigative workshops, guided by the knowledge of scientists and engineers (Outreach Workshops in STEM [OWS], 2013). In all, OWS provides STEM enrichment programs that aim to enhance curricular concepts in ways students may not get to experience normally in their science and math classes.

This is particularly relevant given that the STEM education is not formally named in the Ontario elementary science and technology curriculum. However, the document does call for cross-curricular and inquiry-based instruction; but this is most prominent for the science and technology subjects. Integration of mathematics and design (engineering) elements is also present, but as mentioned, it is not formally mandated (Ontario Ministry of Education, 2007). Consequently, it is not surprising that the OWS provides STEM learning experiences that for the most part differ from students’ regular classroom experiences. Although the curriculum document encourages educators to teach in a manner that parallels integrated and inquiry-based STEM education, there is no specific requirement to do so, thereby impacting the level to which teachers’ STEM teaching and practices may be affected in my study.

Workshops are offered for the following subjects: science and technology, mathematics, and some special interest topics (i.e., climate change, constructing musical instruments, etc.). Different workshops are provided depending on the geographical area: Ontario, Alberta, as well as workshops in French for Ottawa. As this study takes place in Ontario’s Greater Toronto Area, the workshops in question will relate to the Ontario programs. In Ontario, the workshops are divided into appropriate levels for kindergarten, primary, junior, and intermediate divisions,
with some of the workshops being suitable for more than one grade and/or division. The science workshops are aligned with the four strands of the Ontario elementary science and technology curriculum: Understanding Life Systems, Understanding Structures and Mechanisms, Understanding Matter and Energy, and Understanding Earth and Space Systems (Ontario Ministry of Education, 2007; OWS, 2015). Furthermore, they are designed to address the expectations as set out by the curriculum documents. Workshops are half a school day in duration with the presenter supplying all of the necessary materials and setup. The workshop presenters are often referred to as ‘scientists’ and come from diverse education and career backgrounds (OWS, 2013). This thesis will use the terms scientist, OWS presenter, OWS facilitator, and workshop leader interchangeably.

There are four main features that distinguish an OWS workshop from a typical science class. These include access to resources, duration, but most importantly inquiry-based, hands-on instruction, as well as the preparation, knowledge, and know-how of the presenter. Firstly, the workshops often include resources and activities that are not normally available for classroom STEM teachers to employ. These can range from model kits, building materials, chemical substances, to owl pellets. In some cases, these materials are not accessible for every STEM teacher, classroom, or school, as in the case with owl pellets and microscopes. With the appropriate funding, almost anything can be made available to schools and students, but the reality of the situation dictates this to be a major limitation for the majority of STEM classrooms. Other materials and equipment used by OWS are in fact everyday things that have been adapted or transformed to aid in a specific activity or experiment.

The second feature contrasting the workshops from an average science class is the duration. As previously mentioned, the workshops run for half the school day, or about two-and-a-half hours. A rotary middle school has periods that average 40 to 50 minutes each. This
is almost three times less than one workshop. This means that a teacher has significantly less time in a given period to explore as many topics and present them in the same ways that can be done in an OWS workshop. Certain activities and experiments simply require longer periods of time to introduce, set-up, perform, consolidate, and clean-up; all of which exhaust what little, valuable time STEM educators have available in each period. This becomes a greater problem when one considers that in many rotary schools, teachers and students move to different classrooms throughout the day and week. Thus, it may be impractical or maybe even impossible to leave behind a prepared experiment or activity to be continued on a different day. From another perspective, when constructing knowledge themselves, different students may need varying amounts of time to make the same discoveries. So while a top-down, teacher centered lecture can fit into a regular 40 to 50 minute class period, student-led inquiry often takes more time. The greater time allotment available during the OWS workshops promotes more organic, inquiry-based learning in students. Furthermore, the OWS presenters arrive with all of their resources, prepared and ready to go. This cuts down on much of the preparation time teachers would have to undergo and fit into their hectic daily timetables.

The third, and probably the most important difference that OWS offers, is authentic hands-on inquiry instruction. Although each OWS workshop has several activities and experiments that students participate in, the majority involve students doing hands-on work to construct knowledge. Instead of listening to a lecture or reading a text, students are given the opportunity to explore and discover, which is an important part of STEM education (DeCoito, 2014; Fioriello, 2010). Despite all of the attention, resources, and professional development (PD) dedicated to STEM education, traditional, didactic teaching continues to be the most common pedagogical approach. Thus, OWS addresses the existing disconnect between theory and practice; a STEM education that continues to be ‘business as casual’ (Sanders, 2009).
The final feature relates in part to the third, whereby the OWS presenters possess the knowledge, know-how, and necessary preparation to conduct hands-on, inquiry-based learning. The presenters are specifically trained to conduct the hands-on activities as opposed to just learning ‘about’ them (OWS, 2013). Whether they have personally created the activities, taught other presenters, or been taught themselves, they have expert knowledge and proficiency. This is significantly different from the vast majority of professional development opportunities available to teachers whereby they are expected to listen and discuss theory, strategies, and examples without accumulating specific, first-hand experience of how to conduct the experiments and activities (Davis, 2003).

In theory, these four factors can be overcome so that they no longer contrast with, but rather reflect a typical STEM class. Although budgetary constraints are always an issue, the everyday materials used by OWS could be affordable for schools. In fact, many schools have plenty of science equipment going unused, but not enough time for teachers to organize and prepare correlating lessons. Ideally, a restructuring of the school day and period scheduling could offer longer periods for STEM inquiry, a rather large policy matter that would be difficult to enact. Alternatively, since the workshops tend to involve multiple, smaller activities, these segments could in theory fit into multiple science periods over the span of a few days. It is these smaller activities that can provide students with hands-on, inquiry-based knowledge building, as opposed to the ‘traditional’ lecture style lessons. Herein lies the most essential factor: helping STEM teachers develop specific, hands-on inquiry activities, experiments, and pedagogical practices. Teachers can observe such instructional strategies from either participating in OWS or participating in a form of PD that could teach such approaches. This in turn, would better prepare educators to teach STEM education.
The hope is that by participating in OWS, teachers will gain first-hand knowledge of an inquiry-based approach to STEM instruction, and subsequently learn to incorporate these elements into their own teaching practices. Self-efficacy is also a key factor of the effectiveness with which teachers can enact the aforementioned elements (Davis, Petish & Smithey, 2006). Vicarious experiences, which are those experiences modelled by someone else, are a main source of self-efficacy (Bandura, 1995). In this study, teachers had the opportunity to experience another educator’s successful teaching of STEM content. It is hoped that seeing the effectiveness of certain strategies, activities, lessons, etc. will positively influence teachers’ beliefs in their own self-efficacy; mainly demonstrating that they too can enact similar processes to achieve similarly successful classroom teaching. More will be said about this in Chapter 2.

In summary, although there is plenty of research outlining the benefits of outreach programs for students, there is little work on the effects of outreach programs on teachers. My study hopes to address some of these gaps in the literature by looking at a unique form of teacher STEM PD in this large southern Ontario school board. Thus, my research attempts to shed light on the effects of STEM outreach programs on teachers’ content knowledge, practice, and self-efficacy. In addition, I explore the viability of a STEM outreach program designed for students, as a PD opportunity for teachers. The connection between self-efficacy and teacher practice is one of the analytical constructs in this study. I will analyze whether the STEM outreach workshops can affect teachers’ instructional practice by promoting their self-efficacy. In general, Bandura’s (1995) self-efficacy theoretical construct provides a useful understanding of human behaviour and learning. Thus, people who have great confidence in their abilities and their knowledge of how to use these abilities, have a greater likelihood of being successful in related courses of action. In my study, educators will participate in OWS workshops that implement appropriate, integrated, and inquiry-based STEM instruction. The question I am
asking is whether the teachers’ observation of and involvement in these workshops will in any way promote confidence in their abilities to enact similar STEM instruction in their own teaching.

1.2 Research Questions

The following research questions are used to explore the impact of teachers’ participation in STEM outreach workshops.

- Can teachers’ participation in the OWS workshops increase their content knowledge, and if so how?
- Can teachers’ participation in the OWS workshops increase their confidence, and if so, how?
- How do OWS workshops provide teachers with a repertoire of new pedagogical approaches?
- Can the OWS workshops provide a viable source of professional development, and if so, how?

1.3 Researcher Positionality

The need for addressing research positionality stems from concerns regarding subjectivity (Bogdan & Biklen, 2003; Creswell, 2013). Particularly, that a researcher’s own preconceived notions, perspectives, and attitudes may influence data collection, analysis, and any resulting conclusions. It is often expected that researchers will gather an objective picture of the phenomenon under study, but this is challenging in light of our innate human subjectivity. To help overcome this, researchers employ specific research tools and methods that can help limit this subjectivity. Bogdan and Biklen explain that most preconceived opinions are pretty shallow, and that the volume and detail of data that is collected should be effective in portraying a much more accurate state of affairs which inevitably contradicts some preconceived ideas.
Furthermore, researchers have to acknowledge their biases, and subsequently reflect on them throughout the study. This conscious attention to biases allows researchers to limit their effects. In addition, as the investigator presents his or her own background, history, and interests, s/he prepares the reader for making a critical analyses of the study, in light of what the reader now knows about the investigator. The following is a description of my own research positionality, my experiences, and my personal educational journey.

I commenced this Master’s work after completing a Bachelor of Education with teaching specialties in science, biology, and chemistry. At the same time, I began working as both an occasional teacher in elementary and high schools as well as a research assistant with Dr. Isha DeCoito, the principal investigator (PI) on the longitudinal STEM study. This thesis work presents a section of the data that I have collected and worked on throughout the longitudinal study. As previously mentioned, the main goal of the longitudinal study was to explore the impact of the outreach workshops on students’ and teachers’ efficacy in STEM.

As a fresh graduate from the Faculty of Education, I was eager to enter my profession, expecting opportunities to bring forth innovation and change to the education system (as many new graduates are). Upon starting my teaching work, I was slightly let down by the lack of subject integration, authentic inquiry, and innovative pedagogy that I had heard and learned so much about. Once I began filling in for more long-term teaching positions, I too felt the pressures, expectations, and realities of the job that limited my implementation of innovative teaching methods. Although I felt quite confident in my abilities and self-efficacy to enact such teaching, I found out how difficult it was to implement it. Fortunately, it was around that time that I had the opportunity to participate in the observations of the Outreach Workshops in STEM, as part of the data collection on the longitudinal study. I was also fortunate in being able to find several science education focused graduate courses, which allowed me to continue my
own pedagogical education. I was experiencing both the practical side of what integrated, inquiry-based STEM education should look like, while learning more about its theoretical underpinnings.

Despite having several longer-term teaching positions, I am still a novice occasional teacher with little opportunity to bring what I am learning, observing, and writing about into my practice. As a research assistant on Dr. DeCoito’s STEM longitudinal study, I had the opportunity to administer teacher and student surveys, conduct workshop observations, as well as conduct all of the teacher and student interviews at the end of Phase II. I have also assisted in the data input of the surveys and the coding of interviews and open-ended questions. What I present in this thesis is my independent and original interpretation of the data. I have also worked with Dr. DeCoito on writing proposals and presenting some of the preliminary findings at conferences. My two-and-a-half year involvement in this study has provided me with intimate knowledge of the research methods and participants. This in turn has allowed me develop valuable insights into the emerging findings. It is my interest and experience in this field of work that has led to the writing of my Master’s thesis on this topic.

In light of my educational and professional background, I am interested in how genuine inquiry and integrated STEM teaching can be brought into the classroom. My (albeit limited) experience revealed that this type of science and math teaching is not commonplace in the schools where I have worked, volunteered, or conducted fieldwork. Thus, I am curious how this problem can be addressed and feel that teacher PD can be one avenue whereby teachers can be exposed to these alternative pedagogies. My initial participation in the OWS workshops has taught me, not only specific teaching activities, but also general guidelines, approaches, and other transferable skills that I believe will positively impact my own STEM teaching. Hence, I believe that the teachers participating in the longitudinal study could also benefit from these
workshops as a potential form of PD. This idea contributed to the formation of the research questions guiding this project.

Consequently, I began this research work doubting whether integrated, inquiry-based pedagogy was in fact taking place in schools. I met the teacher participants for the first time when we began survey data collection in Phase I of the longitudinal study. I had the opportunity to meet with the teachers again throughout Phase I and Phase II of the study. By the time the semi-structured interviews took place at the end of Phase II, I believe I had developed a casual and friendly rapport with the interviewees to help limit some aspects of the observer effect (Bogdan & Biklen, 2003). As Daniels (1983) points out, the closer the relations you develop with the participants, the more wary you have to be of the findings you present and how you present them. For instance, if a particular participant has been extra friendly and helpful in moving your study forward, you may naturally feel grateful. This gratefulness can in turn subconsciously impact your future analysis of this helpful participant. Although I met with the participants on more than one occasion, there were no real opportunities to develop closer relations. In the next section, I introduce the context within which this study is situated.

1.4 Study Context

For the purposes of this study, the schools have been given the following pseudonyms: Middlegate (MG), Northwoods (NW), Ferncreek (FC), and Hillview (HV). The industry partner funding the longitudinal study selected the four schools because they all ranked ‘high’ on the Social Risk Index (SRI) (Southern Ontario School Board [SOSB], 2008) at the commencement of the study. The SRI is described as:

…a general picture of socio-economic vulnerability in Canadian communities.

The index contains nine Canadian census variables that profile the socio-economic context of communities: average household income, unemployment
rate, education level, owner-occupied dwellings, mobility, knowledge of
Canada’s official languages, recent immigrants, lone parent families, and
government transfer payments (SOSB, 2014).

According to the more recent version of the SRI report (SOSB, 2014), school MG is now ranked as ‘somewhat low’ risk, schools FC and NW are ranked as ‘somewhat high’ risk, with only school HV still ranking as ‘high’ risk. It is encouraging to see that there are positive changes occurring whereby three of the schools now rank lower on the SRI. That being said, the ‘somewhat high’ and ‘high’ risk schools’ statuses still need to be addressed. As will be discussed in Chapter 2, there is concern that teachers serving at-risk students are not getting the best possible in-service training that would benefit these most vulnerable students. The possibility of using STEM outreach workshops as a form of PD could help address this problem.

Dr. DeCoito, the PI of the STEM longitudinal study, was part of the Faculty of Education at York University, in Ontario, Canada at the start of the study. Since taking a position at Western University, Dr. DeCoito has received the necessary ethical clearance from Western University to continue the study as well as to permit me the use of a section of the teacher data for this thesis project. I have also received ethical clearance from the University of Toronto to use the data from the longitudinal study for my MA thesis. Each workshop observation involved multiple teachers as the workshops spanned multiple rotary periods during the school day. Hence, teachers would have to move to teach their next class after a given period. Because of this, there would sometimes be a teacher present during the workshop who did not teach science or math, and so was not part of the study. If this occurred, it was explained to these teachers at the beginning of the workshops that a study was in progress, the study’s purpose, as well as what sort of data was being observed and collected. The next section presents the conceptual underpinnings guiding this study.
1.5 Conceptual Framework

My thesis utilizes the following theoretical constructs: social cognitive theory with a focus on self-efficacy and vicarious learning. Bandura’s (1986) social cognitive theory (SCT) is based on the premise that humans learn from observing other humans. Humans seek to replicate observed behaviours that they believe will be advantageous, while limiting observed behaviours that they feel will be harmful. The self-efficacy theoretical construct was also coined by Bandura and has its roots in SCT. It is a belief in one’s abilities to perform a certain action successfully, and in doing so yield the expected outcomes or consequences of that action (Bandura, 1995). Vicarious learning is one of four main factors (the other three being mastery experiences, social persuasion, and physiological and emotional states) that contribute to one’s self-efficacy. Specifically, this factor is named as vicarious experiences from social models. That is, if an individual observes the behaviours of another similar individual, this second person becomes a social model for that given behavior to the first person in question (the observer). Now, if the observer witnesses the social model achieving success or positive outcomes from his or her modelled behaviour, this leads to vicarious reinforcement. This means that the observer becomes more likely to also perform this modelled behaviour so that s/he too can experience the success or positive outcomes (Ormrod, 1995).

In this study, I view the OWS presenters as social models for the teachers in my study. In observing the effective, integrated, and inquiry-based teaching of the OWS presenters, it is hoped that teachers’ self-efficacy will be enhanced as well as content and pedagogical knowledge for teaching STEM. More will be said about this in Chapter 2, the Theoretical Overview and the Literature.
1.6 Significance of the Study

The findings of this study have significance for STEM education, particularly in areas of teacher practice, teacher education, professional development, policy, and outreach. As inquiry-based, integrated STEM teaching is not yet the norm in science and math classrooms, the OWS program can be one such avenue to make it more commonplace. OWS utilizes many of these best practices of STEM education to move away from ‘traditional’ instruction and provide students with interactive and hands-on learning. Administrators, school boards, and policymakers need to re-evaluate current pre- and in-service teacher education to deliver better, alternative pedagogies in STEM education. Pre- and in-service teacher education should evolve from simply ‘delivering’ knowledge to allowing educators to construct knowledge. If teachers can experience integrated and inquiry-based STEM teaching for themselves, there is a greater likelihood that they will not only see its value but that they will also be better prepared to implement it. Arguably, encouraging continued and active participation in STEM outreach programs can positively influence both teachers and students, and ultimately contribute to STEM career choices by students.

1.7 Thesis Outline

This thesis is divided into five chapters. This introductory chapter is followed by a chapter offering a review of the literature pertaining to topics of STEM education and how to address shortcomings in current STEM teaching. Research regarding the impacts of self-efficacy and outreach programs on teachers’ practice is also reviewed in Chapter 2. The third chapter introduces the methodology and design of the study as well as some background on the participants and the outreach workshops. Chapter 4 presents the data and findings from this study. The fifth and final chapter provides a discussion of the results, limitations, implications, a summary and conclusion, as well as future directions for possible research.
Chapter 2: Theoretical Overview and the Literature

This chapter will provide a review of the literature in three areas to address the key themes of the study as reflected in the research questions: issues in science, technology, engineering, and mathematics (STEM) education in Canada and globally; attempts by STEM outreach programs to address issues in STEM education; and perspectives on learning. The chapter concludes with a discussion on how the literature informs the research methodology.

Several theoretical constructs were explored in order to provide the rationale for my study design, including: social cognitive theory (SCT), self-efficacy, and vicarious learning. Some pertinent themes that will be explored in greater detail in this chapter include: under-preparation of STEM teachers, misunderstandings of authentic inquiry, as well as how self-efficacy affects teachers’ practice.

2.1 Issues in STEM Education in Canada and Globally

2.1.1 What is STEM education? To promote clarity and understanding, it is helpful here to outline the definition of STEM education that will be used throughout my thesis. STEM education is a rethinking of the traditional approach to teaching science, math, technology, and engineering; whereby, these four strands are integrated into one “meta-discipline” (DeCoito, 2014; Fioriello, 2010; Howard-Brown & Martinez, 2012). The goals of STEM education are to better educate all students in STEM literacy, as well as to combat low numbers of students enrolling in postsecondary programs leading to STEM occupations (DeCoito, 2014; Mishagina, 2012; National Research Council [NRC], 2013).

STEM education needs to integrate two or more of science, technology, engineering and/or mathematics subjects (Sanders, 2009) in a way that pulls away from more ‘traditional’ instructional methods. The National Research Council phrased it well: “Learning science is
something students do, not something that is done to them.” (1996, p. 2). The goal is to have students build knowledge and understanding through inquiry, investigation, problem solving, collaboration, planning, decision-making, and connecting science to practical uses in the real world (NRC, 1996). It is these skills that will help students navigate in a future society, which is increasingly scientifically and technologically advanced. Regardless of whether students choose to pursue a STEM career or not, modern society will require individuals to be scientifically literate in order to function as full members of society. Scientific literacy skills can be achieved through STEM education.

Elements of STEM education resonate well with what experts have deemed necessary learning skills for the 21st century: “adaptability, complex communication/social skills, nonroutine problem-solving skills, self-management/self-development, and systems thinking (National Research Council Board on Science Education, 2010). All STEM subjects possess the potential for the exploration of these 21st century learning skills (Bybee, 2010). This is because integrated STEM education is student-centered, can increase retention, and can promote problem solving and higher level thinking skills (Stohlmann, Moore, & Roehrig, 2012).

2.1.1.1 Inquiry-based pedagogy. Akkus, Gunel, and Hand (2007) explain that traditional approaches employed by teachers do not permit students to build scientific knowledge the way scientists build scientific arguments. Their work focuses specifically on the inquiry-based instructional method of the ‘Science Writing Heuristic’. The approach was found to increase students’ performance when compared to traditional instruction. Interactive, hands-on, and inquiry-based instruction is indeed becoming widely accepted as the way to move forward in STEM education (Howard-Brown & Martinez, 2012).

Inquiry-based learning can be defined as learners discovering essential information on their own, instead of having it presented to them. This distinction is also referred to as ‘guided’
versus ‘unguided’ (or minimally guided learning). Inquiry-based learning can take the form of students doing an experiment or problem-solving; mimicking scientists in order to discover a scientific principle. Critics of this guided-form of teaching and learning define learning as a change in one’s long term memory. They posit that concepts to be learned should be explained fully and directly in combination with strategies that best help transfer new information from working to long-term memory (Kirschner, Sweller, & Clark, 2006).

However, in recent years, interactive, student-centered teaching has come to light as a rival to traditional, didactic teaching (Siemears, Graves, Schroyer, & Staver, 2012). Researchers and educational theorists continue to study its beneficial impacts. They argue that the alternative, direct, guided instruction often presents information in a manner or form that may be incompatible with a student’s current understanding of their world and surroundings. The student would need to first reorganize their worldview before being able to make sense of knowledge transmitted in this format. Unfortunately, many teachers are not knowledgeable in these strategies and/or do not employ them at all or effectively; this topic will be explored further below. The purpose of this study was to observe whether a STEM outreach program could influence teachers in terms of promoting more hands-on, inquiry-based ways of teaching.

2.1.2 The growing need for STEM education. More than ever, highly skilled, educated, creative, and independent workers are being sought after, qualities that can be achieved through STEM education (Howard-Brown & Martinez, 2012). STEM skills are not just for those who wish to pursue studies and/or careers in STEM-related fields. These skills contribute to scientific literacy that is becoming a necessity in our scientifically and technologically advanced world (American Association for the Advancement of Science [AAAS], 1990; Marrero, Gunning, & Germain-Williams, 2014). As Bybee (2010) puts it, “STEM literacy includes the conceptual understandings and procedural skills and abilities for
individuals to address STEM-related personal, social, and global issues” (p. 31). This goes beyond simply preparing STEM professionals, but giving all citizens the tools to navigate our increasingly advanced modern world (AAAS, 1990).

It becomes useful here to distinguish two main goals of STEM education: i) a professional model, and ii) a citizenship-oriented model. A professional model of science education is one that focuses on preparing the STEM professionals of the future. A citizenship-oriented model aims to prepare each and every citizen to be scientifically literate (Feinstein, 2009). However, as Aikenhead (2006) and Feinstein point out, traditional science and mathematics education focuses almost singularly on preparing professionals, thereby losing meaning for the average student who will not pursue a STEM-related career. In other words, the professional model is superseding the citizenship-oriented model. Feinstein goes on to say that encouraging lasting interest in science is best done by showing its relevance to students’ own goals, something that would benefit future STEM and non-STEM professionals alike. Such a lasting interest would educate all students to value a need for a basic STEM literacy, encourage those students already interested to continue in STEM, and inspire those previously uninterested to explore STEM and develop their interest into future pursuits.

It has been argued that individuals without basic STEM literacy will be unable to fully participate as informed citizens in modern society (AAAS, 1990). Feinstein (2009) points out that the role of science and technology in our daily lives is expanding into an increasing number of domains. Future citizens should thus have some understanding of how science is done, the politics around it, as well as the uncertainty and risk involved. In other words, all citizens should be STEM-literate. If they are not STEM-literate, society will unquestionably accept the reality constructed by STEM professionals. This does not downplay the need for skilled STEM professionals, as will be discussed further below. But, as previously mentioned, traditional
science and math education has favoured the knowledge and skills that benefit future STEM professionals while leaving the rest of the citizenry behind (Feinstein, 2009). Integrated, inquiry-based STEM education aims to reconcile these two goals to better prepare all students, whether or not they decide to pursue a future career in STEM.

2.1.3 STEM skills for a global economy. Not only do STEM skills play a role in enhancing scientific literacy, they are also becoming increasingly valuable assets in the workplace. There is evidence to suggest that skills in science, technology, engineering, and mathematics promote innovation, productivity, and economic growth across all industries (Council of Canadian Academies [CCA], 2015). Skills in STEM have come to play a major role in many parts of the economy, however there is concern whether or not Canadians are sufficiently equipped with these skills. In Canada, STEM fields represent 18.6% of all fields of postsecondary studies (Statistics Canada, 2011). Although it is difficult to predict future trends in the economy, labour market, and technological advances, the CCA underlines the importance of maintaining a STEM-literate citizenry to face the uncertainties of the future. While there is conflicting evidence whether there is in fact a current STEM labour shortage in Canada, many believe that future economic, scientific, and technological developments will in fact require greater numbers of STEM graduates and professionals than current projections foresee (CCA, 2015). The conflicting evidence regarding whether or not there are STEM labour shortages could be due to ‘diversion’. This is when individuals with skills in STEM subjects do not pursue STEM studies or careers. As a result of diversion, statistics might show that individuals are obtaining the necessary scores in STEM subjects and so are in theory capable of studying and/or working in STEM. Because these students choose not to pursue STEM related studies and/or professions, we are left with only the illusion that there is enough STEM labour being prepared for the market (Carnevale, Smith, & Melton, 2011). This is quite a troublesome
prospect, as it potentially translates to a shortage in the skilled workforce that will be necessary to sustain Canada’s future economy. Changes need to be made regarding how to prepare and keep individuals in streams leading to future STEM careers.

This issue gains traction as countries like India and China are becoming world leaders in advanced technological industries (Atkinson & Mayo, 2010). Similarly to Canada, the U.S. also believes that there is a need to increase STEM graduates in order to stay competitive in the global economy (Atkinson & Mayo, 2010; President’s Council of Advisors on Science and Technology [PCAST], 2012). The number of STEM jobs in the U.S. are projected to increase by 17% from 2008 to 2018 (Carnevale, Smith, & Melton, 2011). Some studies show that, on average, large metropolitan US cities’ job openings are 30% STEM related, with insufficient numbers of qualified workers to fill these positions (Byars-Winston, 2014). These findings demonstrate that the need for STEM education is both a Canadian and global concern.

In light of all the themes presented above and the attention received by this topic, it is transparent that the engaging, inquiry-based, and integrated aspects of STEM education constitute the best way to move forward in addressing the weaknesses in the current educational and professional systems. Nonetheless, its advantages have not yet become all that visible. In the following section, I will explore the reasons for the apparent lack of success in STEM educational reform, in order to emphasize the need for the outreach workshops that form the subject of this thesis.

2.1.4 Problems with current STEM education. As discussed above, there is growing concern that not enough individuals in Canada and the rest of North America are pursuing STEM studies and careers. Howard-Brown and Martinez (2012) as well as Juuti, Lavonen, Uitto, Byman, and Meisalo (2010) have documented this reluctance amongst students to continue on in STEM fields. In addition, the problem of ‘diversion’ demonstrates that many
STEM capable individuals are not continuing on in post-secondary STEM education and future careers. Carnevale, Smith, and Melton (2011) posit some of the following reasons for this diversion: lack of interest in STEM, social pressures generated by stereotypes of STEM professionals, lack of role models from similar cultural backgrounds, as well as higher earnings in non-STEM jobs. Furthermore, the skills that allow students to be successful in STEM subjects in the first place are also in great demand, and facilitate the transition into other fields. These skills include: critical thinking, problem solving, operations analysis, technology design, and troubleshooting, to name a few (Carnevale, Smith, & Melton, 2011).

However, there is still the question of those who struggle and have not been successful in STEM subjects. Some simply lack the interest and engagement towards STEM subjects to provide the necessary drive to learn about these subjects and study them in the future. In other cases, the stereotypes of STEM professionals may contrast deeply with individuals’ own backgrounds and cultures, thereby further alienating them from pursuing STEM fields. Conversely, a lack of STEM professional role models who do share similar backgrounds or cultures, further adds to this problem. Finally, higher paying non-STEM jobs diminish motivation for seeking out STEM careers. Although the problem of diversion is beyond the scope of this thesis, both STEM competency and interest in STEM careers are needed in order for a student to both choose a STEM post-secondary program and do well in it (Carnevale, Smith, & Melton, 2011).

STEM education needs to address both the problems of effectively equipping students with the necessary STEM skills and also increasing and maintaining an interest in areas related to STEM. As discussed earlier, the future demands both a STEM-literate citizenry in addition to greater numbers of STEM professionals. Even if students have no interest in a STEM career, basic scientific literacy will be beneficial for them to make informed decisions in modern
society. There is thus a need to both spark students’ interest in STEM fields and subsequently maintain it. This will allow all students to attain at least basic STEM literacy, while simultaneously providing more students with the opportunities for future STEM pursuits. Interactive, hands-on, and inquiry-based learning is one such avenue by which STEM subjects can become more engaging, while simultaneously providing more effective learning experiences.

A major problem with much of STEM education is that it is simply science education presented “business as casual” and does not integrate these subject areas or offer better, alternative pedagogies (Sanders, 2009). Didactic, top-down pedagogies continue to be widely used in science and math classrooms, which is especially concerning given that we know how beneficial inquiry-based learning is for promoting critical thinking skills (Marshall & Alston, 2014). One reason for this could be related to Bandura’s (1997) argument that most human activities, such as teaching STEM, have no standard benchmark for adequacy. Therefore, STEM subject teachers may enact integrated and inquiry-based pedagogy to a degree or with a frequency that they judge to be adequate or successful. Since authentic, interactive STEM instruction is not prevalent, these teachers are most likely comparing their practice to colleagues whose instruction is also light on genuine integrated and inquiry-based STEM instruction. Consequently, educators may feel that they are providing enough and correct STEM teaching, when this is in fact not the case.

A district-wide study conducted by Marshall, Horton, Igo, and Switzer (2009) in the southeastern U.S. measured the time teachers spent doing inquiry-based activities in their classrooms. They surveyed the time K-12 science and math teachers spent doing inquiry, as well as what these teachers believed the ideal time spent on doing inquiry should be. Teachers reported that the average amount of their teaching time spent doing inquiry was 38.7% with a
standard deviation of 18.9%. In addition, they reported that the average amount of time they should spend doing inquiry was 57.3% with a standard deviation of 19.5%. Although one could argue whether 57.3% is an adequate percentage of time students should be doing inquiry, it is notably higher than what teachers in this study report they actually do. The findings that inquiry is being done less than 40% of the time in this large school district underscores Sanders’ (2009) claims that much of STEM education is still not employing interactive, inquiry-based teaching. In their discussion, Marshall et al. suggest that long-term professional development (PD) initiatives should allow teachers to actually practice and improve new inquiry-based teaching activities. My study explored the potential of a science outreach program to serve as an innovative form of PD that could help increase inquiry-based instruction for STEM subjects.

2.1.4.1 Issues in STEM professional development. Although there is much literature promoting increased duration and longer-term PD opportunities, reports on the impact of these interventions are inconsistent (Supovitz & Turner, 2000). In particular, Kennedy’s (1998) review of studies in science and mathematics teacher PD did not find much support for either of these claims. Her work did not find a strong relationship between student learning and teacher PD that lasted longer or was spread-out, in the long-term. For instance, Hill’s (2011) study of teacher mathematics learning opportunities found that teacher math PD was rarely reaching the most targeted demographics from a policymaker’s standpoint. She describes how teachers working in schools of low socioeconomic status (SES) performed, on average, significantly worse on measures of mathematical knowledge for teaching. She goes on to say:

Yet these low-SES schools serve students who would benefit from having teachers who are more prepared than the average U.S. middle school teacher. Ideally, the teachers more in need of mathematical knowledge would not only sign up more often for the professional development listed, but also engage in
the opportunities (including MSPs and content/methods coursework) that were more likely to be mathematics-intensive. (Hill, 2011, p. 219).

Her study concluded that with the exception of math-science partnership workshops, less mathematically knowledgeable teachers did not participate in more or less math PD or undertake math PD that was centered on content knowledge (Hill, 2011). Working with teachers in low SES schools, my goal was to observe whether the Outreach Workshops in STEM (OWS) program could serve as a more effective form of PD than the traditional expert-led, didactic-style PD workshops.

Professional development provision is further complicated by the reality that teachers are free to choose most of their PD programs/workshops/experiences. So although they may be involving themselves in a great number of PD opportunities, these may either be focused in a particular curriculum area, or be widely diverse. This results in PD that is fragmented, disjointed, or overlapping. As noted by Kennedy (1998), Hill (2011), and Wilson (2011), teachers may report participating in a great number of PD hours or sessions, but the amount of new content delivered and/or learned may not be reflective of the volume or amount of PD teachers have experienced. Furthermore, there is sparse empirical research to support the impacts and effects of current PD methods on teacher practice and student learning (Wilson, 2011). My study aims to concretely measure any effects the OWS program may have had on teachers by comparing their attitudes, beliefs, and practice before and after the workshops.

Much of teacher PD takes the form of direct and/or guided transmission. An expert runs the workshops and the teachers act as passive recipients of knowledge (Mueller & Welch, 2006). As mentioned earlier, unguided instruction has gained significant acceptance as a better teaching approach. Furthermore, unguided instruction has been shown to be effective when instructing teachers, and so should be incorporated in teacher PD initiatives (Davis, 2003;
Krasny, 2005). Teachers should be learning in inquiry-based, interactive ways if they hope to successfully implement these techniques in their own classrooms. Marshall and Alston (2014) reported that educators improve when PD specifically targets transitioning teachers from lecture-style lessons to ones that engage students in questioning, reasoning, modelling, and explaining concepts. Therefore, the current approach to PD is failing to improve teachers’ understanding and implementation of STEM practices. Ideally, STEM teacher PD should incorporate interactive and inquiry-based learning opportunities (Davis, 2003).

My study, therefore, looks at a possible alternative to traditional PD. Participating teachers had the opportunity to experience up to two different STEM outreach workshops over the course of the school year with each covering different curriculum content and using different inquiry-based activities. The intention was to increase the teachers’ opportunities to learn more and different content while reducing repetition. Furthermore, the workshops took place on the school site during instructional time. There was no extra requirement or commitment placed on the teachers. As my study took place in four schools of lower-SES, this could address the issue of ensuring that teachers working with the neediest children get to experience the best possible pedagogical practices. Hopefully, this could address Hill’s (2011) aforementioned findings that teachers in more challenging schools are not getting the better preparation that students in these schools so desperately need. Providing teachers with in-class PD in addition to regularly scheduled PD could presumably translate into better learning for students and in turn more opportunities for a future not constrained by lower SES. If teachers learn and subsequently employ these best practices in STEM teaching, such as having it integrated, and inquiry-based, this could help bridge the achievement gap for students of lower SES.

There is much concern about the achievement gap between students of low versus middle, and high SES. Rahm, Martel-Reny, and Moore (2005) discuss the usage and
effectiveness of youth programs and programs taking place after school for bridging this achievement gap. This bridging takes many forms for the lower-SES students, including raising academic scores, promoting rates of high school and college graduation, reducing dropout rates, as well as reducing criminal involvement. Rahm, Martel-Reny, and Moore go on to say that it may be beneficial to focus on how to bring lower-SES youths towards success as opposed to trying to supplement them with success opportunities that they may currently be lacking. I argue that improving teachers’ self-efficacy for STEM teaching could help in promoting successful achievement in STEM fields for lower-SES students, and possibly encourage students to pursue these careers.

2.1.4.2 Issues in teacher practice. At its best, STEM education can provide cross-curricular, innovative instructional practices. The reality is that many STEM classrooms continue to be based in traditional, teacher-centered lectures as opposed to innovative practices like inquiry-based teaching and learning (Capps & Crawford, 2013; Marshall & Alston, 2014). Traditional, didactic, and teacher-centered instructional approaches miss out on the advantages of hands-on, inquiry-based learning. That being said, there are multiple reasons why not all teachers have adopted more student-centered approaches, and by extension are not employing them in STEM pedagogy. These reasons include: requirements to cover overcrowded curriculums, lack of knowledge of genuine inquiry, as well as a lack of resources. Because of this added pressure, educators and administrators often opt for the didactic, traditional approach. The goal being to present as much information as possible so as to meet the great number of mandated curriculum expectations (Siemears et al., 2012). This is not conducive to the meaningful learning that was discussed above, and frequently leads to very superficial understanding of the course content. Thus, the need to cover excessive curricular content limits
the availability of time and willingness of teachers to pursue student-centered, inquiry-based pedagogy.

Additionally, some teachers may feel that they already do sufficient hands-on, inquiry-based teaching when they compare themselves to colleagues who are also doing so with limited frequency and effectiveness. Arguably, most teachers likely do not have an accurate understanding of what authentic, inquiry-based learning looks like. A study performed by Capps and Crawford (2013) examined the use of inquiry-based teaching practices for 30 grade 5 to 9 teachers. The teachers for this study were selected for their interest in conducting genuine inquiry. They had an average of 11 years of teaching experience, 12 science courses at the college level, and they had all attended more than three science PD sessions in their careers. Interviews, classroom observations, and written lesson descriptions led the researchers to conclude that the majority of the participants were not employing standard elements of inquiry in their teaching. Capps and Crawford concluded that most of the teachers had little experience with genuine, scientific inquiry and showed very limited understanding of how knowledge in science is created. For the most part, they displayed limited knowledge of how scientists conduct research and what inquiry-based instruction looks like. Even when they thought they were teaching inquiry lessons, the lessons were largely teacher-led and did not permit students to engage in any of their own discovery (Capps & Crawford, 2013).

In summary, misunderstandings of inquiry-based learning can add to the confusion about what STEM education looks like. Taken together, these two factors provide some concerning revelations regarding the current state of STEM education. Sanders (2009), Ejiwale (2012), and Bybee (2010) all contend that STEM education is widely misunderstood and that STEM teachers are not well prepared to teach STEM in an inquiry-based manner. Teachers’ misunderstandings of inquiry is one of the concerns of this thesis.
2.1.4.3 Insufficient teacher preparation and support. Many science and mathematics teachers need better preparation in their content knowledge and pedagogical practices, in order to be effective in inquiry-based STEM instruction (NRC, 2010). For instance, in Canada many elementary teachers are ‘generalists’ and as such do not have specific training or educational background in science and math. Consequently, some teachers may lack the confidence to teach topics they are not familiar with and so be more likely to skip or gloss over them (Yoon et al., 2006). Additionally, teachers at the elementary level may be missing the support, resources, and facilities necessary to effectively employ STEM instructional strategies (Howard-Brown & Martinez, 2012; PCAST, 2010). Resources are a limiting factor in that the average science classroom operates mostly with pen and paper. Teachers lack the materials or ‘kits’ that would allow them to engage students in hands-on inquiry work. Furthermore, their classes are limited to desk workspaces and overcrowded with aging materials and resources; preventing the creative work of authentic inquiry. Without the necessary resources, teachers may struggle to make STEM instructional practices effective. This in turn leads many students to lose interest, motivation and to not succeed in these subject areas. Despite all of the research, media attention, and educational reform in support of STEM education, there continue to be issues with its implementation. Contrarily, as mentioned earlier, STEM education is not formally mandated in the Ontario elementary science and technology curriculum. Although the curriculum does outline a science and technology education that parallels best practices in STEM education, without a formal requirement to do so, many teachers may lack the incentive to implement it in their practice. In order to help address these concerns, support for educators can take the form of PD, instructional materials, and professional learning communities.

2.1.4.4 Recommendations for intervening in STEM education. The Council of Canadian Academies (2015) recommends “early and sustained investment in STEM” in order to
reap long-term benefits in our increasingly scientifically and technologically advanced society. One way to ensure early and sustained investment in STEM is to increase funding for in-service teacher development. Increased funding for programming and resources will equip schools and educators to better deliver STEM curriculum. Another way is to introduce STEM to children at an early age. Introducing children to STEM at an early age not only promotes future interest in STEM studies and careers, it also enhances skills in critical thinking and reasoning as well as overall academic development (Howard-Brown & Martinez, 2012). In order for such STEM education to be successful, teachers need to be experts in the content knowledge of these subjects, as well as be proficient in STEM pedagogical practices. Traditional instructional methods and ‘cookbook’ lab courses need to evolve to be more engaging, relevant, and effective (PCAST, 2012). Instructional methods must spark interest for STEM in students and capitalize on situational interests. ‘Situational interest’ occurs when an external stimulus narrows one’s attention and evokes an emotional reaction to that specific content (Hidi & Renninger, 2006). Hidi and Renninger define situational interest as when someone becomes captivated by an article found in a magazine in a waiting room, even if s/he normally has no interest in its subject, or a child interacting with a new math game or software despite the child not particularly liking math. In these cases, the interest of the individual in question is sparked by the situation; either a new software or magazine article to explore. In the classroom, it is situational interest that first grabs students’ attention and opens them up to accepting further knowledge. The use of computers, puzzles and group work have been suggested as good avenues for initiating situational interest.

This is consistent with Bandura’s (1995) self-efficacy theoretical construct in that an individual’s confidence and outcome expectations determine their actions and behaviours. If an individual feels confident in his or her ability to manipulate the aforementioned math software
or read and understand the magazine article, the individual in question will be more likely to
effectively execute these actions. Furthermore, if they expect the outcome of their actions (i.e.
the usage of the math software or the reading of the article) to provide for them some interest or
value, this further strengthens their likelihood to effectively accomplish these actions.

In my study, the OWS workshops offer a range of activities to spark situational interest,
including collaborative group work as well as problem solving for various challenges and
puzzles. The teachers in my study could potentially benefit by learning from OWS how to
employ such activities in their own classrooms. Sustaining student interest is the consequential
next step to ensuring that further learning takes place. Juuti et al. (2010) present the following
avenues whereby this learning can occur: tutoring, project-based learning, and cooperative
group work. Because the OWS workshops utilize project-based learning and cooperative group
work, they can serve as a vicarious model for teachers to observe and subsequently adapt these
approaches into their own practice.

Situational interest is contrasted by ‘individual interest’. Individual interest is a lasting
tendency to continue reengaging with specific content, along with the accompanying emotional
and neurological responses (Hidi & Renninger, 2006). An example of this would be when a
person finds a magazine article on a topic s/he has been actively exploring and trying to
understand. The feeling of excitement and motivation to read and find out even more on the
subject would be an individual interest. It is this factor that can motivate students to further
explore STEM topics or ideas independent of their teachers. This type of individual interest can
be developed when students are able to build knowledge through interactive and challenging
activities (Hidi & Renninger, 2006; Juuti et al., 2010). These types of interactive and
challenging learning activities are reminiscent of integrated, inquiry-based STEM teaching.
Such teaching approaches contrast drastically with traditional ‘top-down’ instruction taking place in most STEM classrooms.

In Marshall’s and Alston’s (2014) study mentioned earlier, they provided PD opportunities for science teachers that were centered on implementing genuine inquiry in the classroom. After teachers employed the newly acquired inquiry teaching skills, students showed significant gains in student proficiency in science skills and concepts. Taken together, these findings suggest that effective instructional practices can in fact initiate, maintain, and advance students’ interest in STEM (Juuti et al., 2010).

In order to make these effective instructional practices commonplace in the classroom, the appropriate professional development is necessary. That is, teachers need to be provided with a more comprehensive understanding of authentic, inquiry-based learning as well as an understanding of the evolution of their role from presenter to facilitator. This way, STEM educators will be better equipped with the knowledge and instructional practices to engage in and promote interest in STEM. Additionally, the impact of these PD initiatives needs to be researched for effectiveness and best practices (Nadelson, Callahan, Pyke, Hay, Dance & Pfiester, 2013). Subsequently, my study looked at the potential of a STEM outreach program to address some of these issues in terms of influencing teacher content knowledge, pedagogical practice, self-efficacy, and serving as a viable source of professional development.

In my study, teachers had the opportunity to participate in the OWS program with their students, where successful inquiry-based teaching was modelled. The OWS program is not formally a teacher PD opportunity. It is a program for students whereby the classroom teacher is present and expected to be involved. My study aimed to look at whether this student program could also be an effective form of PD for teachers. By taking an active role in the workshops, teachers were actually involved in the inquiry-based teaching process as opposed to simply
observing it. My study is unique in that it brings this PD opportunity to the teachers while their students are also participating. This offers a novel area for exploration of teacher PD as there are many concerns regarding the adequacy of current approaches to teacher PD (Bray-Clark & Bates, 2003).

Furthermore, with respect to teacher training, the current pre-service teacher education program should also be revitalized. The National Academy of Education (Wilson, 2009) offers the following suggestions for programs preparing teachers in general:

- More courses required for entry or exit in their chosen content area (i.e., mathematics or reading);
- A required capstone project (for example a portfolio of work done in classrooms with students or a research paper);
- Careful oversight of student teaching;
- A focus on providing candidates with practical coursework to learn specific practices;
- The amount of opportunity for candidates to learn about local district curricula; and
- Student teaching experiences that are aligned with later teaching assignments in terms of grade level and subject area. (Wilson, 2011, p. 3)

Although all of these aspects may benefit pre-service STEM teachers specifically, some of them go beyond the scope of my thesis. However, practical coursework and more careful oversight of student teaching could be applied to this research. Specifically, teachers can be tasked with trying to replicate similar activities that they have observed in the OWS workshops with observation and feedback from the OWS presenter themselves or another colleague.
For any of these recommendations to be effective, educators must truly believe that a change in their teaching practice is necessary. Not only do they need to be taught, shown, and explained the benefits of inquiry-based STEM instruction, educators need numerous chances to see and try it for themselves. Finally, teachers must be guided, supported, and given feedback as they transition from conventional, teacher-led instruction into more interactive, inquiry-based practices (Marshall & Alston, 2014). This can be achieved through the aforementioned careful oversight of student teaching. The following section examines STEM outreach workshops along with their characteristics and relevance to my study.

2.2 Attempts by STEM Outreach Programs to Address Issues in STEM Education

2.2.1 STEM outreach programs. STEM outreach programs are programs that provide students with hands-on experience and inquiry-based instruction. STEM outreach programs have gained widespread recognition as an effective instrument for introducing STEM options, careers, and degree programs (Nadelson & Callahan, 2011) as well as for increasing students’ knowledge of scientific inquiry and the nature of science (Rahm, Martel-Reny, & Moore, 2005). Such programs go beyond the conventional classroom experience, providing real-world connections and additional skills to both students and teachers (DeCoito & Gitari, 2014; Thomasian, 2011). Kelter, Hughes, and Murphy (1992) point out that teachers enjoy actively participating in science inquiry workshops, and that this may lead to increased self-efficacy. These types of outreach programs often model inquiry-based, hands-on teaching instruction that is a fundamental element of STEM education (DeCoito, 2014; Fioriello, 2010). I have already argued that teachers learn from science inquiry workshops as they watch and participate with their students, further lending support to the idea of utilizing OWS as a form of PD. At this
point, it becomes useful to discuss the role of vicarious experiences in affecting self-efficacy (Bandura, 1995).

**2.2.2 Vicarious experiences.** Vicarious experiences occur when we learn from observing others. This idea forms the basic premise of Bandura’s (1986) social cognitive theory (SCT), which will be explored below. In the meantime, Ormrod (1995) offers a helpful understanding of vicarious experiences through the lens of vicarious reinforcement. She defines vicarious reinforcement as “a phenomenon whereby a response increases in frequency when another (observed) person is reinforced for that response” (p. 275). For example, an OWS presenter may receive positive comments of approval from the students after demonstrating to students how to perform an engaging inquiry-based activity. This positive response suggests to the OWS presenter that the demonstrating to students s/he performed was well received and so s/he should continue to employ it in future workshops in order to once again elicit such a positive response. This becomes a vicarious experience from the perspective of the classroom teacher who observed this entire scenario unfold. Although the teacher did not perform the demonstrating to students or receive the positive response from the students, the teacher is now aware that if s/he employs similar modelling to that of the OWS facilitator, s/he should also garner a positive response. This is considered vicarious reinforcement because the teacher’s demonstrating of similar activities to their students will now become more frequent after observing the OWS presenter’s demonstration be reinforced and rewarded.

Vicarious experiences provided by social models is the factor that has the second greatest influence on one’s efficacy beliefs (after mastery experiences, which will be discussed below). As was mentioned in the earlier sections of this chapter, Bandura (1997) points out that there is generally no universal or absolute standard by which to measure one’s performance of an activity. Often we must resort to comparing our achievements with those of others on a
similar task to determine how well or poorly we have done in comparison. In this respect, the school setting is an ideal context because it does in fact provide a benchmark for students to measure their levels of success based on their grades. In this study, the STEM teachers observed the OWS facilitators successfully integrate inquiry into science lessons. The hope is that in observing and participating in these outreach workshops, STEM teachers’ self-efficacy in enacting similar types of inquiry-based lessons will increase.

To better understand the influence of vicarious learning on self-efficacy, it is worth having a deeper look at the five main contributing factors that affect vicarious experiences: performance similarity, attribute similarity, multiplicity and diversity of modeling, coping and masterly models, and model competence. As mentioned above, there is no absolute benchmark by which to judge the level of our failure or success for most of our actions (Bandura, 1997). This notion was touched upon briefly throughout this chapter to help demonstrate that many teachers do not have adequate benchmark levels to compare to in terms of STEM instructional practices. Thus, teachers compare their outcomes with those of other educators undertaking the same or similar actions. For instance, the teachers in my study experienced having an OWS presenter come into their class and teach their students. Hence, the teachers observed the OWS presenters’ skills, knowledge, rapport with students, teaching styles, and activities used. Whether subconsciously or not, the teachers might then compare their own approaches with those of the OWS presenter.

Although the OWS program is directed at students, teachers need to be present during the workshops and the expectation is that teachers become involved with the activities being done. Thus, whether knowingly or not, teachers compare themselves as well as their teaching methods and styles to those of the workshop leaders. In doing so, teachers in my study were able to gauge their own relative confidence and level of ability in implementing inquiry-based
teaching. As teachers witnessed the success of the OWS instructors, it was hoped they would gain confidence in their own abilities to teach STEM through more hands-on, interactive lessons as well as an increased desire to do so. In this way, the OWS instructors served as vicarious models for the teachers in my study.

However, the level of influence that such a comparison has on efficacy beliefs, depends on the similarities or contrasts between the teacher and OWS presenter. The greater the similarities between the teacher and the OWS facilitator, the greater the effect on the teacher’s self-efficacy. To be more precise, the influence on efficacy beliefs is greater when comparing oneself to someone who is already quite similar in characteristics and attributes. Likewise, the impact is lessened when comparing oneself to someone who is quite different. In recognizing these similarities in oneself, it becomes easier to project the successful individual’s actions onto yourself. “The greater the assumed similarity, the more persuasive are the models’ successes and failures.” (Bandura, 1997, p. 87). Bandura’s SCT is once again useful for helping understand external influences on learning and motivation. I posit that there is ample similarity between the teachers and the OWS presenters in my study. Both the teachers and the OWS presenters are STEM educators working in a classroom setting. In addition, the two parties are likely to employ a fair amount of common behaviours, such as questioning and classroom management strategies. Thus, it is my belief that the teachers in my study do identify with the OWS presenters, and therefore will be naturally encouraged by their example. As a result, if an OWS presenter carries out a novel, hands-on investigation with the students, the classroom teacher should recognize that s/he could also conduct this type of activity in the absence of the OWS facilitator. In this context, the OWS facilitators have served as the social factors that were observed by the participants in this project, potentially affecting participants’ efficacy beliefs.
Furthermore, self-efficacy beliefs are particularly susceptible to increases and decreases when the person in question has not had much prior experience with the given task. Many STEM teachers have not had much experience in genuine STEM teaching and learning. As was discussed earlier, Capps’ and Crawford’s study (2013) demonstrated that experienced and very skilled teachers taught ‘inquiry’ lessons that were teacher-centered and did not permit students to perform their own discovery. In my study, teachers implemented inquiry-based teaching only ‘about half the time’. Thus, it is my belief that one reason for this could be teachers’ limited experience with and significant misunderstanding of authentic inquiry-based learning. The teachers in my study had the opportunity to see integrated and inquiry-based STEM instruction modelled successfully by the OWS presenters.

As the OWS program involved numerous inquiry activities, it is my belief that the teachers in my study had several opportunities for witnessing various modelling of authentic inquiry and integration of STEM subjects. One such activity involved identifying the species of preserved specimens of unknown organisms by examining specimens of familiar organisms and using a taxonomic key. In another activity, students built bridges out of newspapers and then tested each group’s bridge to see which one could support the greatest weight. In yet another workshop, students compared the strengths of hydraulic and pneumatic systems to lift a load. The OWS workshop activities will be expanded upon in Chapter 4, but this sample demonstrates some of the activities where students were building-up their own knowledge by engaging in genuine inquiry work. It is these types of teaching activities that align with inquiry-based instruction and contrast sharply with the traditional, didactic approach to teaching. The OWS presenters modelled teaching behaviours that were positively reinforced by students’ attitudes, participation, and engagement. By extension, this created a vicarious experience for teachers
who were then also reinforced to implement similar hands-on, inquiry-based pedagogy. The following section further explores vicarious learning, self-efficacy, and SCT.

2.3 Perspectives on Learning

2.3.1 Self-efficacy as a theoretical construct for analyzing learning. Self-efficacy is the “belief in one’s capabilities to organize and execute the courses of action required to manage prospective situations” (Bandura, 1995, p. 2). It is a belief in what you can do with your skills, talents, and resources under a multitude of diverse situations. Knowledge of how to complete a task in combination with the necessary required skills are often not sufficient for optimal performance of said task. For instance, conditions that instill doubt in one’s abilities can cause subpar performance even in persons who usually excel on such a task (Bandura & Jourden, 1991). Furthermore, individuals who do not possess high confidence in an activity in a specific field or area tend to avoid other challenges in these fields or tasks. These difficulties can take on forms such as the amount of effort required, precision, creativity, and self-regulation. On the other hand, the greater the belief in efficacy, the stronger the will to persist in a given task, thereby increasing the chance that the task will be completed effectively (Bandura, 1997). For STEM educators to effectively integrate and implement inquiry-based pedagogy, they need to possess sufficient efficacy beliefs that they are in fact capable of implementing integrated and inquiry-based STEM teaching. The notion of self-efficacy is rooted in social cognitive theory (SCT) and so SCT is the best starting point for the analysis of self-efficacy.

SCT describes learning and motivation as being influenced by both observation and modeling. Humans learn by observing the modelled behaviours of others, as well as by observing the consequences of these behaviours. A positive consequence of an action teaches the person that the original action was advantageous. Conversely, a negative consequence
teaches that the original action was disadvantageous. These consequences can be experienced by the person in question, or the person can observe a peer experiencing these consequences. Advantageous behaviour then has an increased likelihood of being repeated by the person in question, while the opposite is true for behaviours deemed disadvantageous (Ormrod, 1995). The observing of behaviours and consequences serve as inputs that become analyzed by the brain.

Furthermore, these experienced and observational inputs can influence humans in a multitude of ways and differently for various individuals. It does not negate the notion that individuals are born with certain behaviours and inclinations to acting in certain ways, rather it also acknowledges the tremendous impact social factors have on human behaviour (Bandura, 1986). Bandura (1997) explains that a person’s courses of actions are not solely decided by stimuli from the environment prompting his or her brain to act in certain ways, instead, people too have significant control over their thoughts and actions. Personal cognitive, affective, and biological factors work in tandem with one’s behaviour as well as stimuli from the environment to all be simultaneously affecting each other. How a person influences him or herself predicts how the person shapes him or herself and what s/he does. Bandura states that “the greater the foresight, proficiency, and means of self-influence, all of which are acquirable skills, the more successful they are in achieving what they seek.” (p. 8). In adapting the notion that people can in fact have an impact on their own behaviour, this study therefore uses self-efficacy as a measure for the likelihood of the participants’ success in teaching STEM. This becomes particularly relevant in a learning environment, whereby impacts on self-efficacy can affect educators and in turn students.

Another perspective on self-efficacy is presented by Pajares (1996) who also addresses some of the challenges of the self-efficacy perspective of learning. He mentions the specificity
needed in measuring efficacy beliefs. Pajares states this is necessary to determine whether in fact efficacy beliefs will have positive or negative predictive value in terms of assessing academic and performance beliefs of an individual. In other words, measures of self-efficacy cannot be generally applied across all domains, but rather specifically to given tasks or criteria. Pajares also discusses the division of ‘self-efficacy for performance’ and ‘self-efficacy for learning’. Performing a task that one has had previous experiences with automatically affects how one believes s/he can handle such a situation again. In contrast, when individuals are learning something new, they have no previous benchmark to compare to. Hence, when individuals are judging their success of learning this new piece of knowledge, they refer to previous accomplishments that are deemed similar or relevant to serve as the benchmark reference point. This is important to note as this study deals with self-efficacy in an educational setting. Specifically, I looked at STEM educators’ self-efficacy in enacting integrated, interactive STEM teaching. The outreach workshop intervention was focused on STEM topics and inquiry-based ways of learning them. The Science Instruction scale where teachers reported on their teaching practice involved specific elements that are present in the workshops. These include: hands-on investigations, using tools to gather data, and making testable predictions, amongst many others. It is my belief that the measure of influence on teachers’ practice is accurate to the intervention taking place, and so has accurate predictive value.

Support for the use of self-efficacy measures in academic settings is provided by Zimmerman (2000). He describes the benefits of being able to predict academic performance outcomes using measures of self-efficacy. Zimmerman echoes Bandura by mentioning that motivation for learning is more greatly affected by self-efficacy than it is by outcome expectancies. He goes on to say that it would be more advantageous for educators to work on improving positive notions of self-efficacy in students rather than simply trying to reduce the
anxiety associated with academics. My research examined the possibility of extending these benefits to teachers as well. Rather than simply trying to reduce the stress of having to deal with constantly evolving educational theories, ministry mandates, school board policies, etc., I argue for the potential of improving practice by improving self-efficacy. By increasing teachers’ confidence and belief in their abilities to teach genuine, integrated and inquiry-based pedagogy, the idea is for the teachers to bring these improvements into their classrooms.

A study by Martin, McCAughty, Hodges Kulina, and Cothran (2009) demonstrated the impact of teachers’ efficacy on the improvement teaching practice. The study, conducted in the U.S., measured the implementation of a new physical education (PE) curriculum after an intervention based on promoting self-efficacy in novice teachers. The implementation of the PE program by the novice teachers in this study was compared to that of a control group who did not receive this PD intervention. In the study, 15 novice PE teachers were paired with 15 ‘expert’ PE teachers. Both groups received PD workshops individually, and later together. The earlier PD demonstrated how to implement the new PE curriculum, while the later PD focused on assisting the novice teachers with its implementation through social cognitive theory approaches. The study took place over the course of the school year, with the intervention and control groups of teachers doing surveys that measured their self-efficacy in implementing the new curriculum as well as in overcoming barriers to teaching the new PE lessons. The intervention teachers attended multiple PD sessions and participated in ongoing mentorship from the experienced teachers throughout the year. The training and mentorship was aligned with the principles of social cognitive theory in order to specifically influence self-efficacy. The expert PE teachers served as models for the novice teachers, creating a similar dynamic to that in my study between OWS presenters and the teacher participants. At the end of the study by
Martin et al., the results showed that the intervention groups increased in self-efficacy for teaching the new PE curriculum, while the control group decreased in self-efficacy measures.

My research aims to apply a similar reasoning to STEM subjects. Participating teachers reported their self-efficacy for teaching STEM before and after experiencing the STEM outreach workshops. Several other monitoring scales were included as well. The prediction is that teachers will end up with greater confidence and skill in teaching STEM, and that these benefits will likely be passed on to their students. This is the focus of my thesis. Bandura’s SCT suggests that mastery and vicarious experiences, one’s physiological state, and the judgements passed on oneself from society and others, impact one’s efficacy beliefs (Bandura, 1997). I now present a discussion on the impacting factors.

2.3.2 Factors affecting self-efficacy beliefs. According to Bandura (1997), there are four main sources contributing to one’s self-efficacy beliefs: mastery experiences, vicarious experiences provided by social models, emotional and physiological states, as well as verbal persuasion. The following is a discussion of the remaining three factors, as vicarious experiences were explored above. Any of these sources may be present either alone or in some combination with the others to determine a particular influence onto one’s self-efficacy.

2.3.2.1 Mastery experiences. Enactive mastery experiences are those where an individual successfully completes a task. This directly demonstrates that the individual possesses the knowledge and ability to do so. Failure however, has the opposite effect, as it further decreases one’s confidence in his or her capabilities. This is especially true when someone has yet to achieve a belief in his or her ability to be effective in a given task. Mastery experiences is the factor that most greatly affects self-efficacy beliefs. Once a person has determined s/he is able to execute a task successfully, s/he is better equipped to face challenges
and spring back from set-backs. For example, the teachers in my study who have closely and carefully been involved in the activities of an OWS workshop may come to feel that they can also carry-out similar activities on their own. Once they become convinced of this fact and engage in performing such an activity, there is a commitment to follow-through. Difficulties that may arise do not appear to be insurmountable, as teachers know that they are capable of carrying-out the activity. If an obstacle does arise, the teachers know that there is a solution to the problem; it simply has to be found, it does not warrant abandoning the activity altogether.

2.3.2.2 Emotional and physiological states and social persuasion. The third and fourth factors that influence self-efficacy are an individual’s emotional and physiological states as well as the verbal persuasion they experience (Bandura, 1995). Stress, tension, physical and mental pain lead one to think s/he is performing poorly. Similarly, negative moods can decrease people’s beliefs in their abilities while positive moods increase these beliefs. It is the interpretation of one’s affective, emotional, and physical states and not simply the magnitude or intensity of the response that influences efficacy beliefs. On the other hand, verbal persuasion takes the form of verbally encouraging or coaching a person that s/he is able to succeed in a given task. When this occurs, there is a greater likelihood that this person will then apply more effort and maintain it for a longer duration of time to try and achieve that goal. This is in contrast to the negative mindset and doubts s/he would otherwise revert to if problems or challenges arose in the lack of such positive verbal persuasion. It is important to note that social persuasion on its own has a stronger negative impact than it does a positive one. Specifically, it is easier to persuade someone they are not capable of being successful on a given task than it is to convince them that they are (Bandura, 1995).

However, emotional and physiological states and verbal persuasion do not factor into my study and so I do not explore them further. The most prominent aspect affecting self-efficacy in
this research are vicarious experiences from social models, which have been introduced above. In any case, none of these four influences are particularly informative on their own when it comes to measuring the level of self-efficacy beliefs. It is only when an individual processes and analyzes any of the influences that they become factors in affecting one’s beliefs in his or her abilities. This cognitive awareness and understanding is key in translating any of these four influential elements into actual influence (Bandura, 1995). This underlines the need for active reflection on the part of the teachers if the OWS program is to be effective in influencing efficacy beliefs. The OWS was not a formal teacher PD program, and so it did not include opportunities for teacher reflection. To address this concern, my study included teacher reflection and open-ended questions that asked participants to reflect on any impacts the workshops may have had.

In my observations of the outreach workshops, my intention was to witness teachers getting actively involved in the activities being organized by the OWS facilitator. I assumed that this involvement would be reflected in teachers’ practice in their regular classrooms as teachers brought with them the newly acquired content knowledge and instructional strategies learned in the workshops. The surveys that the teachers completed before and after participating in the workshops included scales to measure efficacy beliefs and science instruction. Ideally, the results of these scales would have demonstrated an increase in teachers’ confidence to effectively teach STEM subjects along with an increase in their implementation of integrated, inquiry-based methods of teaching in the classroom setting. Furthermore, semi-structured interviews were conducted with the teachers to also help determine if the workshops had any effect on teachers’ self-efficacy and STEM teaching practice. I also reasoned that the teacher participants recognized the OWS presenters as successful implementers of integrated, inquiry-based STEM pedagogy. Furthermore, in experiencing the workshops, the teachers identified the
skills and abilities they most lack, and subsequently aimed to replicate these behaviours from the presenters. In addition, the conversations that took place between the teachers and OWS presenters as during the workshops were beneficial. Specifically, these could serve as the ‘deliberate expression of thought processes’ as the presenters were communicating to the teachers the ‘what’, ‘how’, and ‘why’ of their behaviours and actions.

It is necessary however, to mention that there is often a delay between the observation of modelled behaviour and its subsequent imitation in practice (Masia & Chase, 1997). That is, an individual may experience vicarious learning by observing the reinforcement of a modelled behaviour, but the individual may not replicate this reinforced behaviour until a later time. Similarly, an individual may experience vicarious punishment of a behaviour, but not actually cease this behaviour until later on. This delay in vicarious learning between observation and replication could also factor into my study. Although teachers observed the OWS presenters teach STEM in an integrated and inquiry-based manner, teachers may not replicate these teaching strategies until a later time. Thus, teachers may report on the data collection instruments that their pedagogical strategies remain unaffected by the workshops, possibly because of this delay in vicarious learning. It is worth considering what impact this may have on my study’s findings.

**2.3.3 Summary of the theoretical overview of learning.** According to Bandura’s (1986) SCT, we learn by observing others. Bandura (1995, 1997) also recognizes that the physical environment plays a critical role in determining behaviour, without denying that the innate self also guides behaviour. In other words, while the environment we are exposed to influences our behaviours and actions in particular ways, we in fact exert at least some control over what environments we expose ourselves to. By selecting particular physical surroundings and avoiding others, we are essentially guiding what influences will be present to affect our
behaviour, and which will not be. Translating Bandura’s approach into the educational setting offers both insights and new challenges. Essentially the question I am asking is why learn; why engage in a behaviour that will produce learning? Bandura in my view, offers a useful explanation for why people engage with a difficult learning situation with no seemingly positive outcomes or consequences: because they possess sufficient confidence in their abilities that they will be able to overcome obstacles and succeed.

In attempting to understand this viewpoint, it is useful to ask oneself why people would persist in the face of adversity to learn in a given context. When the amount of work, effort, and the responsibility that may come with it seem to overwhelm, why would anyone willingly place themselves in that situation? To answer this question, Bandura’s ideas offer the most useful explanation of human behaviour as it pertains to my study. Despite all the aforementioned hindrances, an individual with high beliefs in his or her abilities and the possibility of executing them effectively to achieve success, could persist in such adversities to engage in difficult learning situations.

In summary, Bandura’s SCT seems to offer the most useful understanding of human behaviour for analyzing the research questions of my study. By extension, the self-efficacy theoretical construct demonstrates a direct impact on performance outcomes in academic settings. This has immediate relevance to my study as the goal of this research project was to observe whether positive influences on educators’ self-efficacy can translate into better STEM teaching practices.

2.4 Chapter Summary

The leading section of this chapter addresses the need for citizens to be STEM-literate, to be active and informed members of society, as well as to be able to compete in the future job
market. Although integrated, inquiry-based STEM education offers an excellent avenue for achieving this goal of STEM literacy, many current math, science, and technology teachers are not prepared to implement this type of pedagogy. My study examines the potential influences of a STEM outreach program on teachers’ STEM content knowledge, instructional strategies, and confidence in teaching this way. It also looks at the overall potential of such workshops to serve as PD opportunities.

Furthermore, I have argued that Bandura’s (1986, 1995, 1997) SCT and self-efficacy theoretical construct offer useful insights into understanding teachers’ learning in my study. In particular, I have looked at the role of these workshops in affecting teachers self-efficacy beliefs with respect to carrying-out similar integrated, inquiry-based instruction. Vicarious experience from social models is the factor affecting self-efficacy beliefs that is most prominent in my study, as the OWS presenters served as models for teacher participants regarding how to implement effective STEM instructional practices. The following chapter presents the methodology of my study.
Chapter 3: Methodology

I utilized a mixed-methods design, which is one where both quantitative and qualitative data are collected to help analyze a research problem (Creswell, 2003). In this chapter I explain why I used this design, followed by a discussion of my methods used, a description of participants and the data analysis procedures.

3.1 Why Mixed-Methods?

As Schutz, Chambless, and DeCuir (2004) put it: “the use of multimethods in a single investigation allows for the potential consideration of rival causal factors.” (p. 277). This allows for both types of data to provide insights into the phenomenon under study; insights that can complement one another, or reveal divergences needing further exploration. I now present two examples of studies employing mixed-method designs.

Howard, Sauced Curwen, Howard, and Colon-Muniz (2015) conducted a study in which they explored students’ comfort levels in employing computers for completing schoolwork tasks as well as for communicating with teachers. This study involved academically at-risk Latino high school students in a computer mediated remedial program. Howard and colleagues utilized a mixed-methods design that consisted of both surveys and interviews similar to my thesis project. The surveys were used to measure students’ comfort levels while the interviews explored some of the underlying reasons behind the survey responses. The researchers explained that the surveys provided a more broad view of students comfort levels that would have otherwise been unattainable within the limited number of interviews. On the other hand, the interviews provided deep and meaningful analysis, but were limited by smaller numbers and so did not provide universally applicable data. Likewise, my study looks to obtain some general views and perspectives from the teacher participants through the use of surveys.
The much larger number of responses possible through the surveys offers a larger sample and in turn, a better representation of STEM educators as a whole. At the same time, my use of interviews aims to dig deeper in order to understand why the surveys reported the findings that they did.

Another study by Russek and Weinberg (1993) also employed a mixed-methods design to measure the implementation of a new technology-based math curriculum. Their study involved classroom observation, interviews, open-ended questions by teachers, as well as multiple quantitative measures. The quantitative measure included checklists, evaluation forms and a self-reporting questionnaire. Although their study focused primarily on qualitative data, Russek and Weinberg found that using both methods positively refined the findings they obtained. For example, the authors used a checklist to measure the quantity of the technologically-based lessons implemented by the teachers and compared it to the quality of the lessons with respect to the expectations. They were then able to construct a scatterplot that mapped the quality versus quantity of the technologically-based lessons. From this scatterplot, the researchers developed new questions, for instance why some teachers who had high quality lessons did so few of them, or vice-versa. Some of these questions spurred the authors to gather additional data to explore these answers. Similarly, my study used the initial findings from the quantitative data to help frame part of the qualitative data collection. Specifically, the results of the surveys guided the types of questions that were developed for the semi-structured interviews. Several emerging themes from the surveys prompted further analysis that was made possible with the interviews.

Consequently, corroboration and complementarity are important aspects of a mixed-methods research design. Schutz, Chambless, and DeCuir (2004) point out the difference between corroboration and complementarity in mixed methods designs. Corroboration can be
defined as obtaining similar data from different data collection instruments. Complementarity on the other hand is an attempt to find different dimensions of the same research problem under study. My study utilizes elements of both corroboration and complementarity. Certain topics are explored and expanded upon in the survey questions, open-ended questions, and in the semi-structured interviews. At the same time, each data collection method also probes some areas unique to that method. The surveys offer a wider breadth of data, some of which is further investigated in the interviews and open-ended questions. For example, one of the statements from the Teacher Efficacy and Attitudes Towards STEM (T-STEM) survey (Friday Institute for Educational Innovation, 2012) appears as follows in Figure 1 (the full survey can be obtained from the Friday Institute for Educational Innovation website, see references):

<table>
<thead>
<tr>
<th>4. I am confident that I can teach science effectively.</th>
<th>O</th>
<th>O</th>
<th>O</th>
<th>O</th>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Please respond to these questions regarding your feelings about your own teaching.</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neither Agree nor Disagree</td>
<td>Agree</td>
<td>Strongly Agree</td>
</tr>
</tbody>
</table>

Figure 1. T-STEM survey sample statement STEB4.

Likewise, one of the teacher interview questions asks: *How do you feel when you are teaching science/math/technology (i.e. Confidence, ability, self-efficacy, etc.)?* (for the full interview protocol see Appendix A). Both this interview question and the survey statement in Figure 1 above ask about participants’ beliefs of their confidence in teaching STEM. Both seek similar results from separate data collection instruments thereby demonstrating corroboration. A further exploration of the T-STEM surveys is provided below.

In addition, complementarity is also achieved as in the following extract of the T-STEM survey (Friday Institute for Educational Innovation, 2012) in Figure 2:
This T-STEM statement is part of the Science Instruction (SI) scale used to track participants’ instructional practice throughout the duration of the study (more details regarding the survey scales can be found below). The Outreach Workshops in STEM (OWS) open-ended questions similarly ask: *Have Outreach Workshops in STEM influenced your teaching practice? If so, how?* (for the full open-ended question protocol see Appendix B). This open-ended question served to measure whether the experiencing of the OWS workshops had any effects on teacher practice. The survey statement in Figure 2 and the above open-ended question focused on different aspects of teachers’ instructional practice to help shed some light on whether there may be a pattern or relationship emerging between the two factors. In sum, the quantitative and qualitative data were used to both corroborate and complement each other. Further justification for this mixed-methods approach involves triangulation and illustration as well as validity and generalizability.

Bryman’s (2006) argument for *triangulation* and *illustration* is the most compelling reason for using mixed methodology for my study. He equates triangulation with “greater validity” and explains that “quantitative and qualitative research might be combined to triangulate findings in order that they may be mutually corroborated.” (pp. 105, 106). As discussed earlier, corroboration was enabled in my study in that participants reported on similar areas in multiple forms of data collection. If the various data collection instruments report
similar findings, one can reason this suggests a greater likelihood that the findings are accurate as opposed to occurring as a result of chance alone. In addition, Bryman describes illustration as “the use of qualitative data to illustrate quantitative findings, often referred to as putting ‘meat on the bones’ of ‘dry’ quantitative findings.” (p. 106). As was mentioned earlier, the qualitative data allowed for more meaningful analyses as it elaborated on certain statements from the T-STEM surveys. The open-ended reflection and interview questions permitted participants to reveal greater details and insights than was possible on the surveys alone. This parallels the aforementioned complementarity, in that multiple dimensions of the same area under study were examined. My goal was to obtain both general data that can be used to make inferences to the whole population, as well as to acquire more detailed, in-depth accounts from participants as explained by Creswell (2003). Different elements of a research project naturally lend themselves better to certain methods, and the hope was to capitalize on these advantages. Thus, I believe it was useful to frame my data collection in terms of corroboration and complementarity, as well as triangulation and illustration. Although there are several parallels in addition to some finer differences between these methods, it is my belief that taking these four ideas in tandem has produced the most useful insights.

On the other hand, Bogdan and Biklen (2003) point out that there are some concerns when combining qualitative and quantitative data. The primary concern being that designing a good qualitative or quantitative study can be challenging enough as is. Bogdan and Biklen go on to say that researchers often struggle to effectively combine both qualitative and quantitative approaches. The end result of this struggle is thus frequently lacking sufficient quality for either a stand-alone quantitative or qualitative approach, let alone a hybrid approach of both. Locke, Spirduso, and Silverman (2007) make a similar argument in terms of distinct quantitative and qualitative ‘worldviews’. Developing a strong sense of either one of these views is left to the
most experienced researchers. Trying to combine the two simultaneously and appropriately is an added level of difficulty. They recognize that there is value in mixed-methods research, but caution that it should be employed carefully, particularly by novice researchers. Because my research originated from the STEM longitudinal study, it is my belief that the experience of the principal investigator, Dr. DeCoito, ensured that her guidance and mentorship allowed me to effectively apply a mixed-methods design to this thesis.

Furthermore, validity and generalizability lend strength to the argument for a mixed-methods design. Creswell (2013) “considers “validation” in qualitative research to be an attempt to assess the “accuracy” of the findings” (p. 249). He goes on to offer several strategies for validating qualitative research and makes the claim that using at least two of these methods should provide a sufficient measure of validity. In my study, three of these methods were most relevant: triangulation, prolonged engagement and persistent observation, and clarifying researcher bias. Triangulation was discussed above and the clarification of researcher bias was presented as part of my researcher positionality in Chapter 1. Prolonged engagement and persistent observation will be explored below when I discuss field immersion.

In addition, generalizability is referred to by Bogdan and Biklen (2003) as what most qualitative researchers describe as the transferability of findings. That is, whether the results and findings of a specific study are applicable to other demographics and contexts beyond the specific study. The participants of this study belong to four different schools spread across different locations in a large suburban city. This helped reduce any inherent biases that may have resulted if participants all belonged to one school or geographical area. Thus, greater generalizability was achieved by having a variety of perspectives across different locations. The quantitative surveys allowed for the gathering of data from a greater number of participants, thus increasing the likelihood that findings are representative of a greater number of individuals.
At the same time, the limitations of this study must also be recognized. The participants in question all worked in schools of lower socioeconomic status in a suburban area of Ontario, Canada. The generalizability of any findings and conclusions will depend on how similar the situation and context of my study is to the situation to which it is being compared (DeCoito, 2000).

On the basis of the above discussion, it is my belief that utilizing both quantitative and qualitative methods will increase the chances of obtaining the most useful and accurate information in my study. If the results from these separate methods complement and support one another, this adds strength to the arguments being put forth as potential theories and explanations of the research question under study. That being said, even if the two forms of data present contrasting evidence, this too is helpful as it presents opportunities for further research that may yield more and alternative perspectives to analyze the issue (Creswell, 2003). A mixed methods approach was selected for this study to help account for some of the inherent biases present in both quantitative and qualitative research methods. For instance, the SI scale of the T-STEM survey queried how often teachers implement inquiry-based instruction in their teaching. However, it gave no explanation or reasoning for the reported frequency. Likewise, an interview prompt asked how teachers would improve their STEM teaching practice and five interviewees mentioned access to and/or management of resources. This interview responses could shed some light as to why teachers implement inquiry-based teaching with the frequency that they do, but because this code only occurred five times, its validity comes under scrutiny. Fielding and Fielding (1986) wrote that “what is important is to choose at least one method which is specifically suited to exploring the structural aspects of the problem and at least one which can capture the essential elements of its meaning to those involved” (p. 34). As the
quantitative data collects a large number of responses to frame the problem as a whole, the qualitative data permits one to perform a much deeper analysis.

In addition, Creswell (2003) points out that “a mixed methods approach is one in which the researcher tends to base knowledge claims on pragmatic grounds (e.g., consequence-oriented, problem-centered, and pluralistic).” (p. 18). This is applicable to my study, as my thesis project concerns itself with the problem of using STEM outreach programs as a potential source of professional development (PD). The effectiveness of these programs is measured by their influences on teachers’ content and pedagogical knowledge, as well as their confidence in teaching it. The consequences of these factors can help one understand whether or not such outreach workshops can serve as viable PD opportunities for teachers.

3.2 Participants and Recruitment

Participants in the study are teachers of sixth, seventh, and eighth grade in four schools in a large school board in suburban Southern Ontario. The participants all came from four schools that were given the following pseudonyms: Middlegate (MG), Northwoods (NW), Ferncreek (FC), and Hillview (HV). Once ethical approval was obtained from the pertinent institutions, informed consent was obtained from all participants. Each participant received a formal, written letter (Appendix G) inviting him or her to participate in the study. The letter provided an outline of the study, its objectives, procedures and the purpose(s) for which the research findings will be used. The letter also indicated the freedom of participants to withdraw at any time and the measures taken to maintain confidentiality of data and participants’ identities. Consent was obtained from the teachers and the principals of the schools involved in the study. The longitudinal study research assistants and I approached the teachers to ask for their participation in the completion of the T-STEM surveys, the teacher reflections, the OWS
workshop surveys, and the OWS open-ended questions. I approached all of the teachers to ask for their participation in the interviews, as I conducted all of the interviews myself.

### 3.3 Methods

**3.3.1 Field immersion.** This study was conducted for a long duration, between Oct 2013 and May 2015. This length of time allowed for prolonged engagement and persistent observation. Creswell (2013) explains that long periods in the field involve learning about the culture of where the research is taking place and developing a trusting rapport with the participants. Over time, the researcher becomes aware of and sensitive to the various factors at play in the field of the given study. This puts the investigator in a better position to recognize the distortions that his or her presence is introducing into the study, also known as observer effect (Bogdan & Biklen, 2003). By becoming aware of the culture surrounding the environment where the fieldwork is taking place, the researcher can do his or her best to maintain the most natural setting. In doing so, the investigator is attempting to be as unobtrusive as possible, in hopes of gathering data regarding the most natural state of affairs. This is in contrast to data gathered in a ‘un-natural’ or artificially simulated situation which would be misinforming as it would not shed light on the true phenomenon being observed. Prolonged engagement and the building up of a trusting rapport thereby mitigate some of the impacts caused by the observer effect.

For instance, I remained open to the possibility that when I administered the surveys and conducted the interviews with novice teachers, these teachers may have felt uncomfortable in sharing their experiences. Because novice teachers are still in the process of developing their skills and confidence in teaching STEM subjects, they may have been worried that their responses regarding pedagogy or content knowledge would reflect on their practice as subpar.
By extension, this may have caused the novice teachers to feel that their professionalism is under scrutiny. To avoid feeling scrutinized, the novice teachers may have provided less accurate responses with regards to their content knowledge and practice so as not to appear subpar. By way of example, genuine, authentic inquiry-based learning is being recognized as a better pedagogical approach. Because these teachers may feel their practice is being judged or scrutinized, they may present slightly misinforming data. Thus, when asked how often teachers implement authentic inquiry in their own classroom, a novice teacher might respond that s/he does so more often than is in fact true.

To help address this observer effect, I had the opportunity to meet with teachers twice or even three times over the course of almost two years before conducting one-on-one, semi-structured interviews. These opportunities took place during T-STEM survey data collection as well as during workshop observations. As mentioned below, I reminded the teachers that the surveys were anonymous. Hence it is my belief that anxiety over judgments of professional practice should have been minimized in these two data collection instruments. The semi-structured interviews took place at the end of the second phase of the study, which marked the end of the second year of the study’s duration. Not only would teachers have noticed no repercussions from participating in the first year and a half, they would also have come to know me better through the casual conversations we had shared during survey administration and workshop observations. Therefore, I believe teachers were quite comfortable to be interviewed by me and open to discussing issues they may have otherwise been not so willing to share. I believe that this helped mitigate any misinformation that may otherwise have arisen if teachers felt their professional practice was being questioned or judged.

3.3.2 Data collection procedure. For this study, I collected surveys (T-STEM and OWS workshop), administered open-ended reflection questions, made field observations, and
conducted interviews. I discuss each one below. The instruments used can all be found in the Appendices. All data collection occurred in participants’ respective schools during school hours. At the start of Phase I, teachers were given T-STEM surveys to collect baseline data prior to experiencing any outreach programming. After participating in the OWS workshops with their classes in Phase I, teachers were provided with a form that had eight open-ended reflection questions. These were collected at a later date so that teachers could complete them at their own convenience. At the start of the second phase of the study, teachers completed the T-STEM surveys again (Phase II pre) prior to experiencing that phase’s workshops. After participating in the workshops in Phase II, teachers completed the T-STEM surveys for a third time (Phase II post) as well as the OWS workshop surveys and open-ended questions. The OWS workshop surveys and open-ended questions were attached to the T-STEM survey in Phase II post. This way, participants could simply complete them immediately following the T-STEM as their students were still completing their own surveys. The interviews took place in the spring, after the completion of the Phase II post T-STEM surveys as well as the OWS workshop surveys and open-ended questions. The interviews were semi-structured with general questions to guide the interviewee while allowing open discussion. The various data collection tools are discussed in the following sections.

3.3.3 Workshop observations. Kawulich (2005) provides an in-depth analysis of participant observation as a data collection method. Greater validity can be achieved in study findings as observation can allow the researcher to garner a more thorough understanding of the phenomenon and context under study. Furthermore, observation allows the investigator to catch nonverbal elements as well as subconscious behaviours and actions. When a participant is being asked a question, whether on a survey or interview, s/he actively has to think about the response. During field observations, the participant may behave more naturally, without ‘actively’
thinking about body language, interactions, behaviours, etc. For example, a teacher may report on a survey that s/he did not find any useful information in the workshop, meanwhile during the workshop itself, s/he became curious and began observing or discussing the activities with the program facilitator. My goal in conducting the workshop observations was to collect data that would otherwise have been inaccessible.

I participated as an objective observer in three OWS workshops. These took place in the middle of Phase I as teachers took part in the workshops with their students. My goal was to observe the presenters, teachers, and students. This included looking at the effectiveness of the workshops at engaging students, teaching integrated STEM content, utilizing inquiry-based approaches, as well as the behavior of teachers during the workshops (for the observation protocol see Appendix C). The majority of the teachers observed are also participants in the study. As explained in the Introduction, not all of the teachers at the OWS program were participants of my study. Workshop observations were organized in such a way that at least one of each type of the workshops was observed as per each grade’s curriculum requirements. For example, if the grade seven Life Systems workshop was booked multiple times (for different classes, or schools), observations were done only once for this type of workshop as the activities would be the same each time. As described previously, there are various workshops offered that are all aligned with the curriculum expectations for that grade level. I observed three workshops while the remaining five were observed by other research assistants on the longitudinal STEM study. Observations of all of the workshops constitute the observation data for my thesis.

The workshop observation protocol was designed by Dr. DeCoito (2015) for purposes of the longitudinal study. The protocol involved two components; an observation checklist as well as written jot-notes. The checklist is divided into three categories: student activities, teacher activities, and scientist activities. Each category has a list of items with a ‘yes’ or ‘no’ option to
check if students, teachers, and scientists (the OWS presenters) were exhibiting that given behaviour. The checklists of each observation are amalgamated to show how each workshop fared in each of the three categories. If a behavior was observed it was simply marked with a ‘Y’ for yes, or ‘N’ for no if the behavior was not observed. The behaviours being observed in the student activities are available in Appendix D.

The performance of teachers and OWS presenters (‘scientists’) were measured by a set of items that differed from those of the students. This was done in order to explore the potential of the OWS workshops to affect teachers’ practice. If successful, teachers would gain the skills and knowledge to be able to replicate similar inquiry-based teaching in their own classrooms outside of the OWS workshops. Although teachers did not have specifically outlined roles for the workshop, they were expected to organically become involved as necessary, helping their students, guiding students’ inquiry work, and assisting with the logistical management of the workshop. I have already argued that if teachers are to be successful in replicating inquiry-based, STEM teaching, they should exhibit behaviours similar to those of the OWS presenters. Thus, teachers’ and OWS presenters’ behaviours were measured using the same items. These behaviours and brief explanations are presented in Table 1 below (DeCoito, 2015).

Table 1. The behaviours being observed in the teacher and OWS presenter activities during the OWS workshops

<table>
<thead>
<tr>
<th>Behaviours</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facilitating</td>
<td>Teachers/presenters promoting student completion of activities without direct instruction; for instance, a teacher/presenter may offer a hint to a student in order to guide the student onto the right track as opposed to directly telling the student what the answer is</td>
</tr>
<tr>
<td><strong>Instructing</strong></td>
<td>Teachers/presenters directly presenting content knowledge to students</td>
</tr>
<tr>
<td>----------------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Modelling</strong></td>
<td>Teachers/presenters demonstrating how to complete a task so that students can replicate the process</td>
</tr>
<tr>
<td><strong>Integrating STEM content</strong></td>
<td>Teachers/presenters combining two or more of the STEM subjects in a lesson/activity</td>
</tr>
<tr>
<td><strong>Assessing</strong></td>
<td>Teachers/presenters examining and evaluating student progress in order to direct successful completion of activities; this can take the form of a teacher/presenter offering feedback to students on their progress so as to inform the students of any areas for improvement</td>
</tr>
<tr>
<td><strong>Inquiry</strong></td>
<td>Teachers/presenters promoting authentic building of knowledge in students; that is, teachers/presenters assisting students in formulating their own questions and approaches to discovering the answers to these questions; inquiry focuses on students coming to their own realization of abstract concepts in contrast to simply completing a task as in facilitation</td>
</tr>
<tr>
<td><strong>21st Century learning</strong></td>
<td>Teachers/presenters promoting 21st Century learning skills (see Table 10, Appendix D)</td>
</tr>
<tr>
<td><strong>Technology integration</strong></td>
<td>Teachers/presenters incorporating technological instruments to help student learning and completion of activities</td>
</tr>
<tr>
<td><strong>STEM career awareness</strong></td>
<td>Teachers/presenters talking about knowledge of careers in STEM to increase student exposure to future career options</td>
</tr>
</tbody>
</table>
The written jot-notes included general descriptions of the workshop activities, successes, challenges, and recommendations.

**3.3.4 Surveys.** Surveys are a method for gathering information through the use of questionnaires. The data gathered is used to observe relationships between variables and for descriptive purposes (Hutchinson, 2004). Hutchinson further analyzes different reasons behind employing surveys. These include trying to comprehend behavior and characteristics of respondents, in addition to looking at their attitudes and opinions. Researchers conducting studies through surveys have to hold the assumptions that participants respond honestly and that the data collected accurately reflect participants’ reality. This is a major assumption that can be considered a limitation of using surveys. It is therefore the researcher’s responsibility to ensure to the best of their ability that those taking the survey complete it as accurately and truthfully as possible (Hutchinson, 2004). While administering the surveys, I reminded teachers of the confidentiality of their responses as was outlined in the consent letters they had signed. This was to promote honesty in responses as respondents could feel comfortable that there would be no repercussions for expressing unpopular views.

In addition, Punch (2003) explains that quantitative research has as its primary focus the study of a relationship between variables. These variables are the elements under study, and we want to know how these variables are distributed, any connections between the variables, and the reasons why. In a truly ‘experimental’ study, the investigator would then manipulate the independent variable to track the corresponding changes in the dependent variables. However, the social sciences have not evolved to include a ‘non-experimental’ approach that uses quantitative methods to observe changes or differences in variables as they occur on their own, that is, without being manipulated.
In my study, the dependent variables being looked at are, teachers’ STEM content knowledge, teachers’ confidence in teaching STEM, and teachers’ repertoire of STEM pedagogical approaches. All three variables originate from my research question as presented in Chapter 1. I qualify the aforementioned variables as ‘dependent’ and the experiencing of the OWS workshops as the ‘independent’ variable. That is, I am trying to find out whether teachers’ participation in these workshops has any impact on the dependent variable. That being said, I do not consider my study to be experimental, despite the potential of considering the participation in the OWS workshops as a treatment/intervention. The OWS workshops are readily available to schools outside of this study, and so it is conceivable that teachers could have exposure to these workshops outside of my study. Additionally, there is no control group of teachers whose confidence, content knowledge, and pedagogical approaches are being measured after not experiencing this form of STEM outreach (although this would undoubtedly make for an interesting area of future research). Hence, it is my belief that the use of surveys in my study provides for a non-experimental quantitative approach to measure any potential, more naturally occurring changes in the teachers after the workshops.

3.3.4.1 T-STEM surveys. The T-STEM survey (Friday Institute for Educational Innovation, 2012), validated and tested for reliability through the National Science Foundation (Erkut & Marx, 2005; Unfried, Faber, Townsend, & Corn, 2014), measures changes in teachers’ confidence and self-efficacy in STEM subject content and teaching, use of technology in the classroom, 21st century learning skills, leadership attitudes, and STEM career awareness. It included the following scales: Science Teaching Efficacy and Beliefs (STEB), Science Teaching Outcome Expectancy, Student Technology Use, Science Instruction (SI), 21st Century Learning Attitudes/Skills, Teacher Leadership Attitudes, and STEM Career Awareness. For my study I used two scales from this survey: STEB and SI. The STEB scale measured participants’ beliefs
about their efficacy in teaching STEM, while the SI scale measured participants’ implementation of inquiry-based teaching. These were multiple-item scales that were obtained by collapsing the scores from the individual items (Punch, 2003). There were 12 items for the STEB scale and 15 for the SI scale with each item employing a five-point Likert scale. It is these two scales that have been used from the T-STEM survey for this thesis. The same surveys were administered at three (time) points to track any changes in participants’ responses over the course of the study. The same T-STEM surveys were given to participants in order to track changes in teachers’ attitudes and beliefs after participating in the OWS outreach workshops. All T-STEM surveys were given to teachers to complete at the same time that students were completing their respective surveys as part of the longitudinal study.

### 3.3.4.2 OWS workshop surveys.

The OWS workshop surveys (Appendix F) were attached to the T-STEM surveys in Phase II post. This survey was created by Dr. DeCoito and consisted of 10 statements utilizing a five-point Likert scale (DeCoito, 2015). These statements explored teachers’ experiences with the workshops in terms of: Practice, Knowledge, Attitude and Self-Efficacy, Professional Development, and Student Learning. Practice consisted of four items that explored effects (if any) of the STEM workshops on teaching practice. Knowledge consisted of one item that explored effects (if any) on teachers’ content knowledge. Attitude and Self-Efficacy were measured using one statement targeted at the influence of the workshops on the teachers’ levels of confidence. Professional Development had two items that looked at the potential of the workshops to serve as professional development opportunities for teachers. Finally, Student Learning was comprised of two items regarding effects on students, which I did not analyze in this thesis as they are not relevant to my research questions.

The aforementioned scales from the T-STEM provided insights into teachers’ beliefs, attitudes, and understandings of STEM as well as how to implement it. As teachers participated
in the OWS workshops over the course of the study, administering the T-STEM after two workshops, and again after four workshops allowed me to track any changes in participants’ responses (as per Figure 3 on p. 72). Specifically, I was tracking any changes in teachers’ beliefs about confidence and efficacy in teaching STEM content (STEB scale) as well as any changes in their instructional practice (SI scale). In addition, the OWS workshop surveys asked teachers whether and how they may have benefitted from the outreach program, and if they would consider it as a possible PD opportunity.

3.3.5 Reflection questions and open-ended prompts. The open-ended prompts served as a springboard for further exploration and analysis on how such an outreach workshop could be used to benefit the classroom educators. Roberts et al., (2014) point out that open-ended questions can offer a clear view of respondents’ thoughts. They do not limit or suggest a particular response, and so provide the truest version of what the respondent is actually thinking and feeling at the time. Open-ended questions were utilized in this study to counter-balance the guided responses obtained in the surveys. The key difference between the two instruments is that the teacher reflections took place after participants experienced two workshops, while the OWS open-ended questions took place after four workshops. Again, this allowed for the tracking of any changes in responses thereby providing some insights as to whether or not the workshops were having an effect.

3.3.5.1 Teacher reflections. Teacher reflections were administered in Phase I of the project, after teachers participated in two OWS workshops. These consisted of eight open-ended questions (Appendix E) given to teachers after participating in the OWS workshops. The reflection guideline examined any influences on teachers’ practice, confidence, and content knowledge, as well as asked for general comments regarding the workshops and effects on students’ learning. I analyzed four of the questions that were relevant to my study.
3.3.5.2 OWS open-ended questions. The OWS open-ended questions were administered at the same time as the Phase II post T-STEM survey (as an addition to the OWS workshop survey and the original T-STEM survey). This tool has six questions (Appendix B) looking at general comments and recommendations surrounding the workshops, influences on students, as well as influences on teachers’ practice and confidence. I have used the two questions focusing on teacher’s practice and confidence for my study.

3.3.6 Interviews. The objective of the interviews was to explore the issue from the thoughts, words, and voices of the participant. “Qualitative interviews are used when researchers want to gain in-depth knowledge from participants about particular phenomena, experiences, or sets of experiences” (deMarrais, 2004, p. 52). Probing questions that evolve from what the interviewee has already shared can offer an exploratory advantage to obtain the most complete version of events.

Interview questions need to be sufficiently open-ended so that respondents can provide deep experiences and knowledge of the topic under study “The open-ended nature of the approach allows the subjects to answer from their own frame of reference rather than from one structured by prearranged questions.” (Bogdan & Biklen, 2003). As the interview develops, the interviewer builds a connection with respondents so that they feel comfortable sharing their experiences, hopefully with vivid detail. Because my interview questions were open-ended, I as the researcher was able to adapt the questions to the context and situation of each interviewee to obtain the most relevant and useful insights. The interviews were ‘semi-structured’, and so an interview protocol (see Appendix A) was in place to guide the general direction of the questioning.

At the same time, there was enough freedom to create a unique environment for the co-creation of knowledge between myself and the interviewee (deMarrais, 2004). Because of the
safe interviewing environment established, the respondents had the opportunity to freely engage in conversation and share more than just the answers to the protocol questions. For instance, when asked about how she felt when teaching science, math, and or technology, Sylvia went on to expand on the ‘Adopt a Physicist’ program she is running at her school. In this program, schools ‘adopt’ a physicist currently working in the field and go on to communicate with him or her, collaborate on student projects and activities, etc. This anecdote by Sylvia demonstrated the effort and innovative instructional methods she is employing in her classroom. If she had been asked a close-ended question or if she had not felt comfortable sharing extra information with me, none of this may have come to light. Hence it is my understanding that the semi-structured interviews provided a wealth of valuable insights into my study.

The interviews took place at the end of Phase II and consisted of 13 questions to guide the conversations. Interviews were 20-30 minutes in length, audio-taped, and later transcribed. These took place in the teachers’ classrooms, school resource rooms, or the school office. Teachers selected the time and place at their convenience, with some opting for phone interviews. Phone interviews also took place during school working hours and with teachers present at their school sites. The interviews were audio-recorded and later transcribed. Subsequently they were coded for major themes as well as patterns and reoccurring ideas. The questions focused on teachers’ understandings of STEM and inquiry, teachers’ practice, any effects that OWS may have had on teachers and students, as well as questions regarding best avenues for PD. The responses for the four relevant interview prompts are included in my analysis.

3.3.7 Rationale for the data collecting instruments. The pre T-STEM surveys administered in Phase I measured participants’ backgrounds, attitudes, and beliefs that they were bringing to the study as base-line data. The workshop observations that took place in Phase I
captured the STEM pedagogy taking place, as well as the interactions of teachers with students and OWS presenters. The teacher reflections at the end of Phase I document the teachers’ experiences with the workshops in addition to any influences the workshops may have had on the teachers’ self-efficacy, content knowledge, and instructional practices.

The T-STEM surveys administered at the beginning of Phase II were identical to those in Phase I. They measured changes in participants’ responses following participants’ experiences with two OWS workshops in the winter of 2013, 2014 (Phase I). In Phase II, teachers received two more OWS workshops. The same T-STEM surveys were once again administered in the second half of Phase II (spring 2015). A complete time line of my study is presented in Figure 3 on page 72. The same T-STEM surveys were used at all three time points in order to measure any changes in participants’ responses throughout the study. The OWS workshop surveys and open-ended questions once again looked at teachers’ experiences with the workshops and any indication that the workshops may have influenced the teachers’ practice, knowledge, and confidence. The semi-structured interviews at the end of Phase II collected the data on the teachers’ teaching practice, knowledge of STEM pedagogy, impressions of the OWS workshops, and once again any effects the workshops may have had.

This combination of both quantitative and qualitative data provides the most rounded and balanced approach to analyzing my research questions. By obtaining quantitative data from many teachers, I was able to better understand the effectiveness of STEM outreach workshops on teachers’ content knowledge, self-efficacy, and teaching strategies. Through the qualitative approach, more in-depth perspectives are revealed that can provide significantly greater clarity into the underlying factors and beliefs surrounding the research problem. Several of the data collection tools query the participants on similar topics, thus providing grounds for corroboration as was discussed. Each of the data collection instruments also captures unique
information to allow for complementarity.

3.3.8 The phases of data collection. This longitudinal study follows a mixed-methods design (Mills, Durepos, & Wiebe, 2010) and involves three phases. Each phase has a quantitative and qualitative element. As my thesis only focuses on the first two phases, the structure of Phase I and II is presented in Figure 3 below:

![Figure 3. Phase I and II of the study.](image)

3.3.8.1 Phase I. Quantitative data consisted of T-STEM surveys (Friday Institute for Educational Innovation, 2012) administered at the start of the school year, fall 2013. The T-STEM surveys utilized a five-point Likert scale. Each teacher subsequently received two OWS workshops in the winter of 2013, 2014 which were observed by myself or other members of the longitudinal study research team. The observation protocol is in Appendix C. In the spring of 2014, teachers completed open-ended reflection questions based on the workshops (Appendix E); making up the qualitative data for Phase I.

3.3.8.2 Phase II. Phase II had a very similar structure with T-STEM surveys taking place at the start of the year (fall 2014), followed by two OWS workshops (winter 2014, 2015). After the workshops (spring 2015), teachers once again completed T-STEM surveys. However, this time each teacher completed an additional OWS workshop survey as well as OWS open-
ended questions (both instruments are available in Appendices F and C). In the final stage of Phase II, 11 teachers participated in semi-structured interviews. Phase II quantitative data was collected from the T-STEM surveys as well as the OWS workshop surveys. The qualitative data was obtained from the OWS open-ended questions as well as the interviews. A summary of the quantitative and qualitative data collected is presented in Figure 4 below. My thesis work only reports on Phase I and II of the longitudinal study as Phase III is on-going.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Timeframe</th>
<th>Quantitative Data</th>
<th>Qualitative Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Oct ’13 - Nov ’13</td>
<td>T-STEM surveys</td>
<td>OWS workshop observations</td>
</tr>
<tr>
<td></td>
<td>Dec ’13 - March ’14</td>
<td></td>
<td>Teacher reflections</td>
</tr>
<tr>
<td></td>
<td>April ’14 - May ’14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>Oct ’14 - Nov ’14</td>
<td>T-STEM surveys</td>
<td>OWS open-ended questions</td>
</tr>
<tr>
<td></td>
<td>April ’15</td>
<td>T-STEM surveys</td>
<td></td>
</tr>
<tr>
<td></td>
<td>May ’15</td>
<td>OWS workshop surveys</td>
<td>Semi-structured interviews</td>
</tr>
</tbody>
</table>

*Figure 4. Quantitative versus qualitative data per Phase I and II.*

**3.3.9 OWS workshops.** As discussed previously, there are various workshops as per the curriculum expectations for each grade level. These workshops were scheduled in consultation with Dr. DeCoito, OWS, and either the school administration or a designated teacher responsible for this task. The workshops were scheduled for the winter in both phases and took place in the teachers’ respective classrooms. This was to allow for sufficient time to do pre surveys at the start of the school year as well as post data collection closer to the end of the school year. The workshops were about two-and-a-half hours or half of a regular school day and all followed the structure presented below. The OWS presenter would bring all of the necessary materials and resources and have everything set up prior to students arriving in class. The workshops began with a brief overview of the topic by the presenter, outlining the
activities, rules, and any safety precautions. This was followed by a minds-on activity that is inquiry-based and hands-on to get the students warmed-up and motivated. The minds-on-activity was followed by some sort of consolidation. This consolidation either took the form of a worksheet or occurred verbally with the presenter. The rest of the workshop consisted of several group and/or individual inquiry-based activities followed by consolidations. The last 45 minutes of the workshop were devoted to a larger group challenge that brought together what was learned throughout the workshop. The majority of the workshops had a takeaway in the form of a worksheet or object made in the workshop. Teachers were present during the workshops with their classes. The workshop observations will be presented in Chapter 4 to provide a more in-depth look at what took place during the workshops. The next section illustrates how the various data were analyzed.

3.4 Data Analysis

I am one of three researchers who analyzed the data in the longitudinal study; however I independently analyzed all of the data presented in this thesis. The main goal was to look for any complementing and corroborating findings to the other data sets, as well as any other unexpected patterns. Corroboration was explored by analyzing whether teachers’ responses were consistent across the various data collection instruments (i.e., if a given teacher reports that they implement inquiry-based teaching all the time on the T-STEM survey but then in an interview says that s/he does so only about half the time). Complementing findings were observed when an explanation or deeper elaboration was pieced together from the various data collection tools (i.e., if a given teacher reported that they implement inquiry-based teaching about half the time on the T-STEM survey and then in the interview s/he explained that this is due to a lack of resources). Finally, unexpected patterns became evident when teachers’
responses were not consistent across the various data collection tools, or when the results contrasted with my hypotheses.

3.4.1 Quantitative data.

3.4.1.1 T-STEM surveys. From the T-STEM survey (Friday Institute for Educational Innovation, 2012), I analyzed the STEB and SI scales. The STEB scale measured teachers’ beliefs about their abilities and efficacy in teaching STEM content, while the SI scale measured teachers’ actual instructional practices (Riggs & Enochs, 1990; Unfried, Faber, Townsend, & Corn, 2014). As discussed above, the responses to the Likert-scale items were collapsed to obtain an overall scale score because “…our interest is not so much in responses to individual items. Rather, the individual item is an indicator of the deeper-level trait or characteristic being measured” (Punch, 2003, p. 33). The deeper-level traits in this case are teacher’s beliefs about their confidence in teaching STEM subjects (STEB scale) and what their instructional classroom practices are (SI scale). The collapsing of the scales was obtained by averaging the scores from the individual statements in each scale. There were 120 surveys from 68 respondents, further details are presented in Chapter 4.

First, SPSS was used to obtain descriptive statistics to get a sense of the distribution of variables. Next, SPSS was used to conduct Generalized Estimating Equations (GEE) to see if there were any significant changes in participants’ responses from the Phase I, Phase II pre, and Phase II post. A GEE was used as there was only partial dependence in the data. The GEE method is effective for longitudinal studies that have correlated data, particularly because it is flexible when dealing with missing data (Homish, Edwards, Eiden, & Leonard, 2011; Lee, Herzog, Meade, Webb, & Brandon, 2007). That is, some of the participants have missing scores if they did not take part in all three T-STEM surveys. When the surveys were conducted at each school, teachers could have been absent for numerous reasons and so were unable to complete
the survey at that stage of data collection. Thus, a GEE allowed the analysis to compare both
the findings of participants who completed the surveys at all three time points as well as those
who only completed them at some of the time points. In total there were 68 teachers who
responded to both the STEB and SI scales throughout the duration of my study. Some of the
participants responded the maximum of three times and some with a minimum of one time.

3.4.1.2 OWS workshop surveys. The OWS survey items were analyzed using SPSS to
obtain the descriptive statistics. This allowed me to see if there were any general trends that
could offer some explanatory value to any of the findings from the T-STEM survey results. The
analysis looked at teachers’ experiences with the workshops in terms of their Practice,
Knowledge, Attitude and Interest, Professional Development, and Student Learning. Practice
refers to any effects the STEM workshop had on teaching practice, while Knowledge refers to
teachers’ content knowledge. Professional Development has to do with the potential of the
workshops to serve as professional development opportunities for teachers. There were 26
respondents and a total of eight items for analysis for each respondent.

3.4.2 Qualitative data.

3.4.2.1 Interviews, open-ended questions, and reflections. Qualitative data were
analyzed through an interpretational analysis framework (Stake, 2000). The interviews, open-
ended questions and reflections, as well as the workshop observations were analyzed similarly
(Bogdan & Biklen, 2003). The interviews were first transcribed by another member of the
research team. The transcriptions provided a body of text that was ready for analysis. All of the
qualitative data sets were coded (by me) for recurring patterns and themes (Bogdan & Biklen,
2003). I did this by highlighting matching themes in the MS Word file using various colours to
correspond to the various codes. I then proceeded to tally the frequency of each code by
counting each occurrence of it being highlighted. I then inputted the frequencies into MS Excel and constructed bar graphs of the codes and their frequency for visual representation.

As the number of responses for each of these instruments were low (reflections = 10; open-ended questions = 26; interviews = 11), I coded themes that occurred at a minimum of two times. There is an exception in the case of the teacher reflections whereby twice I coded a response that occurred only once. This is because only one response in each of these two reflection questions aligned with my hypothesis. Thus, I wanted to highlight these unexpected findings. Although some coding categories overlapped between the four data sets, there were also distinct ones. For example, the interviews, OWS open-ended questions, and teacher reflections all have codes concerning any influences on teachers’ practice (i.e., “yes, it has influenced my practice”). As for an example of the distinct codes, only the workshop observations have codes regarding the level of teacher participation in the workshops (i.e., “teacher doing marking at his/her desk”).

3.5 Participants

There were 68 participants who completed the T-STEM surveys across Phase I, Phase II pre, and Phase II post. Of these 68 participants, 10 completed teacher reflections, 27 completed the OWS surveys as well as OWS open-ended questions, and 11 were interviewed (the various data collection tools did not have distinct groups of participants, rather there was significant overlap between the groups). I will describe the participants who responded to each data collection instrument under each instrument’s dedicated section. I only included names for the participants who completed teacher reflections and interviews as those were the only tools that asked for participants’ names.
3.5.1 Phase I T-STEM survey respondents. Phase I T-STEM surveys had 50 respondents as per Figure 5 below:

![Figure 5](image)

*Figure 5. Phase I: T-STEM respondents’ schools, gender, and years of teaching experience.*

School MG had 11 teachers (22%), school NW had 13 (26%), school FC had 17 (34%), and school HV had nine (18%). This response rate is fairly reasonable given that school FC had the largest student body while school HV had the smallest. Of the participants, 31 were female (63%) while 18 were male (37%). This trend is not uncommon as schools in Ontario continue to have predominantly female teaching staff (Ontario College of Teachers, 2014). One teacher did not indicate gender on the survey form. Teachers’ years of teaching experience were fairly evenly divided with eight having 0 to 5 years (16%), 13 with 6 to 10 years (27%), nine having 11 to 15 years (18%), eight having 16 to 20 (16%), and 11 having 21 or more years (23%). As well, one participant did not report her teaching experience. Unfortunately, only 10 teachers completed the teacher reflections at the end of Phase I.

3.5.2 Phase II pre T-STEM survey respondents. There were 45 teachers who responded on the pre T-STEM surveys as in Figure 6 below:
Figure 6. Phase II pre: T-STEM respondents’ schools, gender, and years of teaching experience.

The breakdown of participants responding to the Phase II pre T-STEM survey is quite similar to that in Phase I. School MG had 12 teachers (27%), school NW had 10 (22%), school FC had 14 (31%), and school HV had nine (20%). There were 28 females (64%) and 16 males (36%). One teacher did not report his or her gender. In terms of teaching experience, 10 reported having 0 to 5 years (22%), 13 having 6 to 10 years (29%), seven having 11 to 15 years (16%), five having 16 to 20 (11%), and 10 having 21 or more years (22%).

3.5.3 Phase II post T-STEM survey respondents. The Phase II post T-STEM survey was administered at the same time as the OWS workshop survey and OWS open-ended questions (these latter two instruments were stapled as an additional page to the original T-STEM survey). There were 27 respondents as shown in Figure 7:
Figure 7. Phase II post: T-STEM, OWS workshop surveys, and OWS open-ended questions respondents’ schools, gender, and teaching experience.

Because there were almost half as many respondents in Phase II post, the distributions of participants changed slightly. School MG had five teachers (19%), school NW had six (22%), school FC had nine (33%), and school HV had seven (26%). There were 16 females (59%) and 11 males (41%). For teaching experience, eight reported having 0 to 5 years (30%), eight having 6 to 10 years (30%), four having 11 to 15 years (15%), five having 16 to 20 (18%), and two having 21 or more years (7%).

3.5.4 Interviewees. Sixteen teachers were selected for interviews based on the frequency of their participation in Phase I T-STEM as well as Phase II pre and post T-STEM surveys. All of the teachers selected had responded on at least two of the three T-STEM surveys, as per Table 2 below. Eleven of the 16 agreed to be interviewed. Brief descriptions of the interviewees are presented below. Pseudonyms have been used for confidential purposes.
Table 2. Interviewees’ participation in each phase of T-STEM administration

<table>
<thead>
<tr>
<th>Teacher</th>
<th>School</th>
<th>Phase I</th>
<th>Phase II pre</th>
<th>Phase II post</th>
<th>Legend</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sylvia</td>
<td>FC</td>
<td></td>
<td></td>
<td></td>
<td>Participated</td>
</tr>
<tr>
<td>2. Felix</td>
<td>FC</td>
<td></td>
<td></td>
<td></td>
<td>Did not participate</td>
</tr>
<tr>
<td>3. Basia</td>
<td>HV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Brandy</td>
<td>HV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Leanne</td>
<td>HV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Trey</td>
<td>HV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Ginny</td>
<td>MG</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Trevor</td>
<td>MG</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Veronica</td>
<td>MG</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Leo</td>
<td>MG</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Theresa</td>
<td>NW</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sylvia has taught for 15 years in both Canada and the U.S. She has taught all grades from K-12. She holds a BA in Sociology, a BSc in Physics, MS in Physics, MSc in Education, and is currently a PhD candidate. Sylvia speaks very highly of the OWS program and regularly involves her classes in other outreach programs as well. She is currently teaching science at school FC.

Felix has been teaching for nine years. He currently teaches grade seven and eight science and math at school FC. His educational background is in business administration and economics, while his teaching subjects are marketing, accounting, and business entrepreneurship. He does not have a science background, but has been teaching science and math for several years.

Basia has been teaching for 17 years. She was teaching grade seven science and math at the beginning of the study at school HV. She holds a Bachelor’s degree in science as well as a Master of Education degree.
Brandy has been teaching for five years and has an educational background in accounting and management. She is currently teaching science and math at school HV and was teaching grade eight at the start of the study.

Leanne has been teaching for 11 years. She has taught grades five to eight and is currently teaching science at school HV. She holds two Bachelor’s degrees, in science and education.

Trey has been teaching for seven years and has taught grades seven and eight math and science. He has a background in physiology and a Bachelor of Education. He is currently at school HV.

Ginny has been teaching for three years. She has taught grades five to seven and is currently teaching math and science at school MG. She has a Bachelor of Arts and a Bachelor of Education. She was the teacher responsible for coordinating the dates of the OWS workshops as well as the dates for data collection for the longitudinal study in her school. She was very helpful and made our work easier.

Trevor has been teaching for 10 years. He has a Masters in Teaching and a background in Psychology. His teaching specialty is Physical Education. He currently teaches science at the grade eight level at school MG.

Veronica has been teaching for 16 years. She has a background in math and is currently teaching math and science at the grade six and seven level at school MG. She has started teaching science in recent years and is continuing to develop her knowledge and expertise in teaching this subject.
Leo has been teaching for 20 years and teaching science for the last two. His teaching subjects include math and special education. He is currently teaching grade seven science at school MG where he has only been for the last few years.

Theresa has been teaching for 33 years. She holds a Bachelor of Science with a major in chemistry as well as a Bachelor of Education. Theresa’s teaching subjects include science and math. She is currently teaching grade seven to eight science and math at school NW.

3.5.5 Teacher reflection respondents. There were 10 respondents to the teacher reflections that took place after the workshop observations. The following six interviewees were also respondents: Leanne, Ginny, Trevor, Veronica, Leo, and Theresa. I now introduce the remaining four teacher reflection respondents. Maggie has been teaching for 25 years and currently works at school FC. She has a Bachelor of Arts and Science as well as a Bachelor of Education. Gloria has been teaching for nine years and is also currently working at school FC. She holds a Bachelor of Applied Science in addition to her Bachelor of Education. Patrick has been teaching for seven years and is currently working at school HV. His teaching background is in social sciences. Monica has been full-time teaching for one year at school NW. She completed a Massage Therapy Diploma as well as a Bachelor of Science and a Master of Education.

3.6 Chapter Summary

My study utilized a mixed methodology in gathering both quantitative and qualitative data. The collection of multiple forms of diverse data allowed for corroboration, complementarity, triangulation, and illustration for the findings. I also addressed generalizability, in that any findings of my study will only be applicable to contexts and situations that are similar to my study. Furthermore, to ensure validity of findings, I engaged in
prolonged engagement and persistent observation. The next section of this chapter explored the methods used, as I have presented an overview of the data collection instruments and the justification of their use: T-STEM surveys, workshop observations, teacher reflections, OWS workshop surveys, OWS open-ended questions, and interviews. This was followed by a brief discussion of my participants and their recruitment. I have then described the specific details of the data collection procedures for each type of data, followed by an explanation of the statistical data analyses methods for the survey data while also speaking to the thematic coding employed for the qualitative data. Finally, I provided a more in-depth background on the participants. The findings are presented in the next chapter.
Chapter 4: Findings

This chapter presents the findings of the research questions presented in Chapter 1; that is, whether teachers’ participation in science, technology, engineering, and mathematics (STEM) outreach workshops influences their professional practice and self-efficacy. My study explored the potential of the Outreach Workshops in STEM (OWS) to increase teachers’ content knowledge and confidence, provide teachers with new pedagogical approaches, and test the viability of the OWS program to serve as a professional development (PD) opportunity for teachers. The findings are organized around the various data collection instruments. These are presented in the following order: OWS workshop observations, Teacher Efficacy and Attitudes Towards STEM (T-STEM) surveys, teacher reflections, OWS workshop surveys, OWS open-ended questions, and interviews.

4.1 OWS Workshop Observations

This data is presented first to outline the nature of the OWS program and confirm whether or not the workshops do in fact offer integrated STEM content in a hands-on, inquiry-based form of teaching. My study’s aim is to see whether these workshops influenced teachers’ STEM content knowledge, self-efficacy in teaching STEM, and repertoire of pedagogical approaches. In addition, I explored the viability of using the OWS program as a form of PD for teachers. The viability of the OWS program as teacher PD is predicated on the assumption that the workshops are in fact offering integrated STEM content and inquiry-based teaching strategies. The following sections provide a look into the OWS workshops to detail the pertinent content and confirm that opportunities for teacher learning occurred. Workshop observations took place after Phase I T-STEM surveys. Figure 8 illustrates the workshop observation findings.
Figure 8. Breakdown of workshop observation findings.

I observed three of the eight workshops, while the other research assistants on the longitudinal study observed the remaining five. Table 3 presents descriptions of the activities that took place in each workshop. The activities are shown by grade. These activities were observed with the use of a checklist and jot notes. The checklists are provided in tables 5, 6, and 7, and were used to track teachers’, OWS presenters’, and students’ behaviours during the workshop. In addition, the jot notes allowed for observation of activities and behaviours beyond those measured in the checklist. The following is an example of a jot note made during the observations: “teacher stopped workshop to ask class a question from what they had already studied: “What is viscosity?” - as the teacher wanted to see what they [the students] remember”. The full observation protocol (with the checklist) is available in Appendix C. Written jot notes were classified under the following categories: students, teachers, workshop leaders, and overall impressions of workshops (in terms of STEM). The following sections present summaries of these written comments.
4.1.1 Student activities in the workshops. For the most part, students appeared to enjoy the workshops. They were engaged when new activities were introduced, but would get bored if the OWS presenter lectured extensively. As the workshops focused on hands-on, inquiry activities, lecturing by the presenters was a rare occurrence. Students greatly preferred the hands-on ‘doing’ activities over traditional worksheets, written exercises, or verbal discussions. For most activities, students worked well in groups. Occasionally there were odd exceptions, where a student would sit out or not get as involved with his or her group. If an activity ran too long or was poorly explained, students would get off task. In follow-up consolidating discussions and worksheets, students were generally able to demonstrate their learning. Overall, the majority of the workshops were successful in both engaging and teaching the students.

4.1.2 Teacher activities in the workshops. Unfortunately, most of the teachers observed were not participating as much as anticipated. Most were disengaged and continued to do their own work. On occasion, teachers would address classroom management issues as they arose. There were a select few teachers who would actively walk around and get involved with the student activities. Often, they would repeat the presenter’s instructions if students were not following specific directions. In their work with a science outreach program, Kelter, Hughes, and Murphy (1992) claimed that teachers enjoyed workshops where they could get involved and participate. Thus, it was my expectation that more teachers would play an active role in the workshops. At the same time, this could possibly explain some of the findings that suggest teachers were not really influenced in terms of self-efficacy and content knowledge. That is, teachers were not making use of the vicarious social models available in the OWS presenters.

4.1.3 Workshop presenter activities in the workshops. The workshop presenters were very knowledgeable about their subjects and activities. They also possessed good command
over the students and were very organized and prepared. In some cases, presenters demonstrated poorer questioning skills. That being said, questioning is a general skill teachers need to develop but not one that is directly related to the impacts I am exploring in this study. Thus, I believe OWS facilitators served as a great model for teachers to observe genuine hands-on, integrated STEM teaching.

4.1.4 Overall impressions of workshops (in terms of STEM). The workshops were predominantly made up of hands-on activities where students could engage in authentic inquiry as opposed to simply having information passed down from the teacher. In addition, most of the workshops did an excellent job of integrating two or more of the STEM subjects. For example, in the grade seven Life Systems workshop (see Table 3, workshop #4) students learned about different root structures of trees in the African rainforest by building their own tree root structures using K’Nex building pieces. The workshop facilitators were well prepared and made effective use of resources. Overall, students were engaged and showed the ability to demonstrate their knowledge during consolidation sessions. For example, in another jot note: “they [students] were making connections to explain compressibility of gases vs liquids” when asked by the OWS presenter in workshop #7 (see Table 3). The presenters were successful in their modelling of inquiry-based and integrated STEM teaching for the teachers in my study and thus I see the merit in measuring any influences from the workshops on my participants. Table 3 below offers descriptions of the specific activities carried out in each workshop. The workshops are listed in numerical order. Student-centered activities are denoted as SC while presenter-led activities are denoted by PL in the Type column.
<table>
<thead>
<tr>
<th>#</th>
<th>Curriculum strand</th>
<th>Grade</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
</table>
| 1 | Earth & Space Systems   | 6     | SC   | • Building end-effector replicating CANADARM out of Styrofoam cups to pick up filled water bottles and a chair  
• Labelling solar system in groups  
• Walking around a peer who is holding up a model moon to observe moon’s shape from different locations (‘moon-phase walk’)  
• ‘Using oversized winter gloves to model astronauts’ experience in space suit gloves by screwing bolts and nuts, stacking washers on a bolt, etc.  
• Using a mnemonic for learning the order of the planets  
• Exploring the relativity of time through the comparing and contrasting of lengths of days and years on different planets  
• Discussing robotics industry, astronauts, Canadian contributions to space exploration |
|   |                         |       | PL   | • Replicating warm air rising over cool air by predicting and testing what happens when warm water (red) is poured into cooler water (blue) in a beaker  
• Exploring the Coanda Effect and viscosity by predicting and testing the path of the water when poured over the side of a cup  
• Exploring Bernoulli’s Principle and the movement of air from high to low pressure through the blowing of air through a straw into a paper cup with a ping-pong ball in it to create better movement of the ball  
• Manipulating various aspects of a model plane design and predicting what will happen based on the modifications; i.e., both flaps down, nose went down; both flaps up, nose went up, tail went down, etc.  
• Using a hair dryer as a source of air current, students manipulated the angles of propeller blades for optimal performance  
• Concluding workshop with students flying their planes |
| 2 | Structures & Mechanisms | 6     | SC   | • Demonstrating Newton’s Third Law of Motion using paddling example and through the releasing of a balloon |
|   | Earth & Space Systems | 7 | SC | Testing toy putt-putt boats powered by candles  
|   |                      |   |    | Exploring the connection of temperature and energy by measuring temperatures of ball-bearings after being shaken  
|   |                      |   |    | Exploring radiation and related technologies through the measuring of the temperature of black versus shiny cans exposed to infrared light  
|   |                      |   |    | PL | Discussing of states of matter, solids, liquids and gases, condensation, sublimation, melting, etc.  
|   |                      |   |    |    | Discussing steam engines  
| 4 | Life Systems         | 7 | SC | Exploring the Brazilian rainforest through chemistry by making silly putty bouncy balls out of borax and ‘secret sap’ (glue)  
|   |                      |   |    |    | Exploring the Ecuadorian rainforest through botany by pouring water over potted plants (rain) and then measuring how much water spilled over in order to calculate how much water each type of plant collected  
|   |                      |   |    |    | Exploring the Southeast Asian rainforest through ecology arranging cards (representing organisms) on a peg board and then using elastic bands on the pegs to connect the various organisms in a food web  
|   |                      |   |    |    | Exploring the Costa Rican rainforest through entomology by using a taxonomic key to identify preserved specimens of insects and small mammals  
|   |                      |   |    |    | Exploring the African rainforest through engineering by using K’Nex building pieces to replicate three tree and root designs in order to test which is taller, better for different soils, etc.  
|   |                      |   |    |    | Completing worksheet in a ‘passport’ at each station  
|   |                      |   |    | PL | Introducing the theme of ecology and the tropical rainforest using a PowerPoint presentation  
| 5 | Structures & Mechanisms | 7 | SC | Building in teams the strongest cantilever by rolling newspaper into beams, then testing with weights to see which team’s structure was the strongest  
|   |                      |   |    |    | Building in teams the tallest free standing structure with two sheets of newspaper and no tape; after 10 minutes, scoring the structures based on height  
|   |                      |   |    |    | Building in teams a bridge spanning two desks using only newspaper and tape; after 20 minutes, testing the bridges to see which can hold the most weight  
|   |                      |   |    | PL | Discussing the strength of different shapes, i.e., triangle versus square  

<p>| 6 | Life Systems | 8 | SC | • Using microscopes to observe and label an onion cell, tomato cell, leaf cell, and animal cell (students having the option of harvesting their own cheek cells or using premade animal cells) |
|   |             |   | PL | • Introducing the use of microscopes and plant versus animal cells; verbally and visually |
|   |             |   |    | • Discussing osmosis as well as high and low concentrations; showing pictures of cells growing and shrinking in high versus low concentration solutions to illustrate the concept |
|   |             |   |    | • Explaining osmosis using a balloon and cup demonstration |
| 7 | Matter &amp; Energy | 8 | SC | • Examining cubes of unknown substances to identify the types of materials by looking at the various qualitative and quantitative properties |
|   |             |   |    | • Using hydrometer to calculate densities of different liquids (water, soap, syrup, and oil) |
|   |             |   |    | • Determining relative velocities by measuring the amount of time it takes a marble to sink in the same four liquids (water, soap, syrup, and oil) |
|   |             |   |    | • Comparing hydraulic versus pneumatic systems using mini dump truck models that use syringes and tubing to replicate the lifting of the cargo bed; students attempting to lift the cargo bed using liquid (water) or gas (air) |
|   |             |   |    | • Building other models that use the syringe and tubing systems to lift objects (tow truck, fork lift, or robotic arm); testing the models by lifting objects |
|   |             |   | PL | • Demonstrating volume by displacement (Archimedes’ principle) |</p>
<table>
<thead>
<tr>
<th>8</th>
<th>Structures &amp; Mechanisms</th>
<th>8</th>
<th>SC</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Building and testing mini catapult models</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>● Using Newton meters to measure the force it takes to pull a vehicle vertically against gravity; and then on two planes, more and less inclined; students performing calculations to determine the amount of work done</td>
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</tr>
<tr>
<td>● Using the same equipment as above, students measure the force it takes to drag a block car on its back while it holds a weight, versus pulling the car holding the weight on its wheels</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>● Exploring friction by replicating the same experiment when the car is pulled on a smooth surface versus sand paper</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>● Using three different pulley systems and Newton meters to measure the force it takes to lift a weight (the conditions are no pulley, single pulley, and multiple pulley systems); students finding that less force is required when using moving pulleys in a multiple pulley system</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>● Imagining a situation where a natural disaster cuts off an island from all supplies and resources; students having to use various simple machines provided to demonstrate how they could move a block (‘supplies’) across a distance of 75 cm between two desks (‘island’ and ‘mainland’); the goal being to use the simple machines to reduce the work and force required to do so; in the end each group presents their designs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>● Demonstrating visually each simple machine and its purposes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>● Demonstrating how to calculate work</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>● Demonstrating pulling books apart with pages interlaced; proving to be much harder when more pages are interlaced because of greater friction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>● Demonstrating levers using a see-saw; a smaller student standing on one end trying to lift a larger student standing on the opposite end of the see-saw; activity being repeated by moving the fulcrum closer to the source of effort (the smaller student); thus making it more difficult to lift the larger student; next the fulcrum being brought closer to the larger student, allowing the smaller student to lift the larger student</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

4.1.5 Observation checklist.

4.1.5.1 Observations of student activities. The items measuring student behaviours were presented in Chapter 3. The results for student activities are presented in Table 4 below.

If a behaviour was observed it was denoted with a ‘Y’ for yes. If the behaviour was not observed, then it was marked with an ‘N’ for no.
Table 4. Checklist of OWS workshops’ student activities

<table>
<thead>
<tr>
<th>#</th>
<th>Curriculum strand</th>
<th>Grade</th>
<th>Group work/Teamwork</th>
<th>Individual work</th>
<th>Communicating/Discourse</th>
<th>Engagement</th>
<th>Problem solving/Decision-making</th>
<th>Questioning</th>
<th>Experiential learning</th>
<th>Hands-on learning/Inquiry</th>
<th>21st century learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Earth &amp; Space Systems</td>
<td>6</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>2</td>
<td>Structures &amp; Mechanisms</td>
<td>6</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>3</td>
<td>Earth &amp; Space Systems</td>
<td>7</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>4</td>
<td>Life Systems</td>
<td>7</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>5</td>
<td>Structures &amp; Mechanisms</td>
<td>7</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>6</td>
<td>Life Systems</td>
<td>8</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>7</td>
<td>Matter &amp; Energy</td>
<td>8</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>8</td>
<td>Structures &amp; Mechanisms</td>
<td>8</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
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<td>Y</td>
<td>Y</td>
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</tr>
<tr>
<td></td>
<td><strong>Total ‘Yes’ (Y)</strong></td>
<td></td>
<td>8</td>
<td>3</td>
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<td>8</td>
<td>8</td>
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<td>8</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td><strong>Total ‘No’ (N)</strong></td>
<td></td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

As anticipated, in all eight of the workshops students had the opportunity to partake in group work/teamwork, communication/discourse, experiential learning, and hands-on/inquiry-based learning. All of the workshops were also effective in engaging the students’ interest. Only the Life Systems workshop for grade 8s (#6) did not provide opportunities for problem solving/decision-making, questioning, and development of 21st century learning skills. In this workshop, students used microscopes to observe plant and animal cells (see Table 3 above).

4.1.5.2 Observations of teacher activities. As discussed in Chapter 3, the performance of the teachers and the OWS presenters (‘scientists’) were measured using the same items. The items were introduced in Chapter 3, and the results are shown in Table 5 below. If a behaviour was observed it was denoted with a ‘Y’ for yes. If the behaviour was not observed, then it was marked with an ‘N’ for no. Both ‘Y’ and ‘N’ were marked if one teacher demonstrated the behaviour while another did not.
### Table 5. Checklist of OWS workshops’ teacher activities

<table>
<thead>
<tr>
<th>#</th>
<th>Curriculum strand</th>
<th>Grade</th>
<th>Facilitating</th>
<th>Instructing</th>
<th>Modeling</th>
<th>Integrating STEM content</th>
<th>Assessing</th>
<th>Inquiry</th>
<th>21st century learning</th>
<th>Technology integration</th>
<th>STEM career awareness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Earth &amp; Space Systems</td>
<td>6</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>2</td>
<td>Structures &amp; Mechanisms</td>
<td>6</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
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<tr>
<td>3</td>
<td>Earth &amp; Space Systems</td>
<td>7</td>
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<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>4</td>
<td>Life Systems</td>
<td>7</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>5</td>
<td>Structures &amp; Mechanisms</td>
<td>7</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>6</td>
<td>Life Systems</td>
<td>8</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>7</td>
<td>Matter &amp; Energy</td>
<td>8</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>8</td>
<td>Structures &amp; Mechanisms</td>
<td>8</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td><strong>Total ‘Yes’ (Y)</strong></td>
<td></td>
<td>5</td>
<td>3</td>
<td>2</td>
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<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>Total ‘No’ (N)</strong></td>
<td></td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>6</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

The first ‘Earth & Space Systems’ grade six workshop has four cells with both Y and N. This is because two teachers were present during the workshop with one exhibiting those four behaviours while the other teacher did not. Both the Y and N from these cells were counted in their respective tally at the bottom of the table. There were four workshops where teachers assisted in facilitating. This is in addition to one workshop where the first teacher did not facilitate but the second teacher did. Teachers provided instruction to students in only three of the workshops. In two workshops teachers modelled expected behaviours for students, assessed students, and promoted inquiry in students’ learning. There was only one workshop where a teacher promoted 21st century learning skills and attempted to integrate technology. In none of the workshops did teachers integrate STEM content or exhibit knowledge of STEM careers.

**4.1.5.3 Observations of scientist activities.** The word ‘scientist’ refers to the OWS workshop facilitator. This checklist used the same items as the ‘teacher activities’ category.
The results are presented in Table 6 below. If a behaviour was observed it was denoted with a ‘Y’ for yes. If the behaviour was not observed, then it was marked with an ‘N’ for no.

Table 6. Checklist of OWS workshops’ presenters (scientists) activities

<table>
<thead>
<tr>
<th>#</th>
<th>Curriculum strand</th>
<th>Grade</th>
<th>Facilitating</th>
<th>Instructing</th>
<th>Modelling</th>
<th>Integrating STEM content</th>
<th>Assessing</th>
<th>Inquiry</th>
<th>21st century learning</th>
<th>Technology integration</th>
<th>STEM career awareness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Earth &amp; Space Systems</td>
<td>6</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>2</td>
<td>Structures &amp; Mechanisms</td>
<td>6</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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</tr>
<tr>
<td>3</td>
<td>Earth &amp; Space Systems</td>
<td>7</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>4</td>
<td>Life Systems</td>
<td>7</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
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<td>N</td>
</tr>
<tr>
<td>5</td>
<td>Structures &amp; Mechanisms</td>
<td>7</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>6</td>
<td>Life Systems</td>
<td>8</td>
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<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>7</td>
<td>Matter &amp; Energy</td>
<td>8</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>8</td>
<td>Structures &amp; Mechanisms</td>
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<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>Total ‘Yes’ (Y)</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>7</td>
<td>5</td>
<td>7</td>
<td>7</td>
<td>5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total ‘No’ (N)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

In all of the workshops the presenters were facilitating, instructing, and modelling. In all but one workshop, the facilitators also integrated STEM content, taught in an inquiry-based model, and promoted 21st century learning skills. This one exception was the grade 8 Life Systems workshop (#6) that was described above as the least successful of all the workshops. It failed to offer inquiry opportunities for students, and made it difficult for the presenter to integrate STEM content, 21st century learning, technology, assessment, or STEM careers. There were three workshops that failed to include assessment, or incorporate technology; however, it was not necessarily the same three workshops in all three instances. Only two workshops made mention of STEM related careers.
4.2 T-STEM Surveys

Two scales were analyzed from the T-STEM surveys (Friday Institute for Educational Innovation, 2012): the Science Teaching Efficacy and Beliefs (STEB) scale and the Science Instruction (SI) scale. The STEB scale looked at participants’ efficacy beliefs in teaching STEM content, while the SI scale looked at participants’ science instruction in the classroom. In total, 68 participants responded to both the STEB and SI scales. Some of the participants responded a maximum of three times and some with a minimum of one time. My study explored any changes to teachers’ self-efficacy and teaching practice after experiencing the OWS workshops in each phase of the study. Hence, teachers completed the T-STEM survey on three occasions: Phase I, Phase II pre, and Phase II post.

4.2.1 STEB scale. GEE analysis was conducted to investigate whether STEB scores on average changed over time. The results of this analysis indicate that the change of STEB scores over time was non-significant, Wald $\chi^2 (2) = 2.18, p = .335$. Table 7 shows that on average participants ‘agreed’ that they have the confidence and abilities to effectively teach STEM subjects ($M = 4.003, SD = 0.5112$).

<table>
<thead>
<tr>
<th>Phase</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>4.001</td>
<td>0.5175</td>
</tr>
<tr>
<td>II pre</td>
<td>4.011</td>
<td>0.5018</td>
</tr>
<tr>
<td>II post</td>
<td>4.003</td>
<td>0.5294</td>
</tr>
<tr>
<td>Overall</td>
<td>4.003</td>
<td>0.5112</td>
</tr>
</tbody>
</table>

4.2.2 SI scale. GEE analysis was conducted to investigate whether SI scores on average changed over time. The results of this analysis indicate that the change of SI scores over time
was non-significant, Wald $\chi^2 (2) = .42, p = .810$. Table 8 shows that on average participants responded very closely to implementing inquiry-based science instruction ‘about half the time’ ($M = 3.173, SD = 0.622$).

Table 8. SI scale descriptive statistics

<table>
<thead>
<tr>
<th>Phase</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>3.183</td>
<td>0.6924</td>
</tr>
<tr>
<td>II pre</td>
<td>3.160</td>
<td>0.6006</td>
</tr>
<tr>
<td>II post</td>
<td>3.212</td>
<td>0.5492</td>
</tr>
<tr>
<td>Overall</td>
<td>3.173</td>
<td>0.6220</td>
</tr>
</tbody>
</table>

4.3 Teacher Reflections

The open-ended reflection questions were administered immediately following the workshop observations that took place from December 2013 to March 2014. There were ten sets of teacher reflections collected. For the full teacher reflection protocol see Appendix E. I analyzed reflection prompts #3, #4, and #5 as they pertained to my research questions. The remaining reflection questions were excluded as they formed part of the longitudinal study; focusing on general comments regarding the workshops as well as influences on students’ learning. The sections that follow present the findings of teacher reflection questions #3, #4a, #4b, and #5.

4.3.1 #3 Has OWS influenced the way you teach science? If so, how? There were ten responses generating the following themes: *it has provided me with new ideas; it has encouraged me to do more hands-on/inquiry; it has reaffirmed importance of hands-on/inquiry; and no, I already do hands-on/inquiry.* Results are presented in Figure 9.
Seven respondents (70%) indicated that the OWS workshops have provided them with new teaching ideas. For example, Monica said “Definitely has given me ideas of things that I could do in the classroom.” Trevor, Patrick, and Gloria (30%) said they felt encouraged to use more hands-on, inquiry-based teaching. As Patrick pointed out “Yes. I now plan to do more hands-on activities and experiments.” Leo and Leanne (20%) wrote that OWS reaffirmed for them the importance of using the hands-on, inquiry-based teaching strategies. Leo said “After observing the students it has reaffirmed that the students in my school need more of this kind of work…” Leanne said that “It reminded me how important hands-on science is to the learning of our students. Behaviour often goes away when kids are engaged.” Veronica and Maggie (20%) responded that they were not influenced because they already implement these ways of teaching. As Maggie said “I have a hands-on science program anyway but I always learn from watching the styles of others.”

4.3.2 #4a. Have OWS presentations affected your motivation and confidence in teaching science over the years? If so, how? This reflection question had nine responses with the following codes: no; I am already comfortable with science; it has motivated me; and it has built up my confidence. The term ‘OWS presentations’ refers to the workshops themselves. The results are in Figure 10.
Veronica, Leanne, and Gloria (33%) wrote that they were not affected and Leanne added that she is already comfortable with the inquiry-based model of teaching. She said “Not really, I already love science and do many of the activities they did, it just made it a lot easier for me.” Leo also said that he is already comfortable with science, but did not explicitly state that he was ‘not’ influenced. He said “I already like science. I know what I am capable of and now seeing the students as a witness rather than a teacher can see more of how they operate.” Thus, Leo and Leanne combined for 22% in the ‘I am already comfortable with science’ category. Trevor, Ginny, and Patrick (33%) said that they felt motivated. As Trevor mentioned “Seeing the students more engaged each time they came in has pushed me to have more activities like the ones they had but having three different classes of Science and having enough items for each class is challenging.” Trevor and Ginny added that this motivation was a result of seeing greater engagement from their students. Patrick on the other hand commented that the presenter was very knowledgeable and so he also wanted to become more knowledgeable on the content matter. Monica, who was in her first year of full time teaching, wrote that she felt more confident because her students were able to demonstrate what she had already taught them. She

*Figure 10. Teacher reflection responses to question #4a.*
said “This is my first year but definitely was a confidence builder when students were able to share things they had already learned in my class.”

4.3.3 #4b. Have OWS presentations influenced you in terms of demonstrating pedagogical strategies for teaching science and technology? If so, how? There were again nine responses presenting the following themes: no; I already employ these methods; yes; and it has given me new ideas. Again, ‘OWS presentations’ refers to the workshops themselves. See Figure 11 below.

Figure 11. Teacher reflection responses to question #4b.

Veronica and Gloria (22%) reported that they were not influenced in terms of pedagogical strategies. As Veronica pointed out “Not really; always tried to use hands-on activities but nice to see other ideas.” In addition to Veronica, Leanne and Maggie (33%) also replied that they already use such teaching methods. For instance, Leanne wrote “I already do demonstrations and experiments with the kids, but I think they are great.” Only Monica responded ‘yes’ saying “Yes, given ideas of demonstrations for certain concepts.” In addition to Monica, Veronica, Trevor, and Ginny (for a combined 44%) also made mention of obtaining new ideas from the OWS presentations. For example, Ginny wrote “It’s influenced me in that I
can refer to the ways the instructors introduced concepts, and experiments that they did that I could replicate."

4.3.4 #5. Have the workshops improved your content knowledge of science, technology, engineering and mathematics? How? This question had ten responses with the following codes: no; I already knew it; and yes. See Figure 12.

![Chart](chart.png)

**Figure 12.** Teacher reflection responses to question #5.

Monica and Trevor (20%) responded that the workshops did not improve their STEM content knowledge. As per Trevor’s response “Not really. Everything that was taught I already knew.” In addition to Trevor, Leanne, and Maggie also commented (for a combined 30%) that they already knew the content. Maggie wrote “I knew much of the material as I have taught science for years and it is a personal interest of mine.” In addition, Leanne wrote

I learned some things from the workshops I don't teach, but most of the content and methods I saw I already do. I did notice that they were able to cover more activities in a short period of time, because they removed the need to do a lab report or any sort of write up from the students.

Veronica, Ginny, Patrick, and Gloria (40%) replied that OWS had improved their content knowledge. These improvements resulted from learning about new real world applications,
about the integration of STEM subjects, and general content knowledge. Patrick wrote: “The workshops have somewhat improved my content of knowledge of science and technology, engineering and math, because it’s evident they are all related and integrated at the same time.”

### 4.4 OWS Workshop Surveys

This survey consisted of ten items measuring various constructs, as was mentioned in Chapter 3. The survey template is provided in Appendix F. Statements #1, #3, #4, and #10 looked at influences on teachers’ practice from the OWS workshops, and so were categorized under *Practice*. Item #2 looked at influences on teachers’ *Content knowledge*. Item #5 reported on influences on teachers’ *Self-efficacy*. Questions #6 and #7 asked participants’ about the value of the OWS workshops as a PD opportunity and so were classified under *Professional development*. Statements #8 and #9 looked at influences on students and so were excluded from this analysis. The descriptive statistics for all of the individually analyzed items are presented in Table 9 below. An explanation for why the *Practice* and *Professional development* items were not collapsed into scales is provided in their respective sections below.

<table>
<thead>
<tr>
<th>Question</th>
<th>Construct</th>
<th>Mean</th>
<th>Median</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Practice</td>
<td>4.077</td>
<td>4.000</td>
<td>0.484</td>
</tr>
<tr>
<td>2</td>
<td>Content</td>
<td>3.577</td>
<td>4.000</td>
<td>0.857</td>
</tr>
<tr>
<td>3</td>
<td>Practice</td>
<td>3.577</td>
<td>4.000</td>
<td>0.703</td>
</tr>
<tr>
<td>4</td>
<td>Practice</td>
<td>3.961</td>
<td>4.000</td>
<td>1.076</td>
</tr>
<tr>
<td>5</td>
<td>Self-efficacy</td>
<td>3.192</td>
<td>3.000</td>
<td>0.801</td>
</tr>
<tr>
<td>6</td>
<td>PD</td>
<td>4.038</td>
<td>4.000</td>
<td>0.774</td>
</tr>
<tr>
<td>7</td>
<td>PD</td>
<td>3.731</td>
<td>4.000</td>
<td>0.667</td>
</tr>
<tr>
<td>10</td>
<td>Practice</td>
<td>3.654</td>
<td>4.000</td>
<td>0.797</td>
</tr>
</tbody>
</table>
4.4.1 Statements regarding practice. This category consisted of four items that when collapsed had a Cronbach’s alpha measure of 0.616. As per George and Mallery (2003), a Cronbach’s alpha of 0.616 indicates questionable reliability. Analysis if items were deleted showed an increase in Cronbach’s alpha to 0.625 if item #1 was deleted. This means that even if one item was excluded, the reliability of the remaining three items together was still questionable. This could occur in a situation whereby one of the four statements was poorer at providing a reliable measure in comparison to the other three statements. Because 0.625 is still a questionable measure of internal consistency, I have not collapsed the four items into a single scale and am considering them separately.

4.4.1.1 #1. The OWS program has provided me with new ideas to use in my science program. There were 26 responses ($M = 4.077$, $SD = 0.484$) suggesting that overall teachers ‘agreed’ that the OWS workshops have shown them new ideas to use in their science teaching. This is not unexpected as this theme is prevalent throughout the findings in this chapter.

4.4.1.2 #3. I have been successful in leveraging the ideas of mentorship from OWS to enhance my science lessons and/or science teaching. There were 26 responses ($M = 3.577$, $SD = 0.703$) showing that overall teachers felt in between ‘undecided’ and ‘agreeing’ with this statement.

4.4.1.3 #4. The OWS program provides hands-on, inquiry based investigations beyond what I am able to provide in my classroom. There were 26 responses ($M = 3.961$, $SD = 1.076$) revealing that teachers are very close to ‘agreeing’ with this statement.

4.4.1.4 #10. The OWS program has influenced me in terms of demonstrating pedagogical strategies for teaching STEM. There were 26 responses ($M = 3.654$, $SD = 0.797$) indicating teachers were in between ‘undecided’ and ‘agreeing’ with this statement.
4.4.2 Statement regarding content knowledge: #2. The OWS program has contributed to my understanding of STEM concepts. There were 26 responses ($M = 3.577, SD = 0.857$) indicating that the majority of teachers’ responses ranged from ‘undecided’ to ‘agreeing’ with this statement.

4.4.3 Statement regarding self-efficacy: #5. The OWS program has increased my confidence in teaching STEM. There were 26 responses ($M = 3.192, SD = 0.801$) indicating teachers were ‘undecided’ about whether their confidence was influenced.

4.4.4 Statements regarding professional development. Items #6 and #7 both relate to PD, however there is some concern whether two item scales can provide an accurate measure of a construct under study. Eisinga, te Grotenhuis, and Pelzer (2013) explain that the Spearman-Brown coefficient is the best measure of reliability for a two item scale; however, they recognize that this does not entirely justify using such a scale as more items would improve reliability. In addition, OWS survey question #6 directly asks participants about their thoughts regarding the potential of using OWS as a form of PD. Because this concretely addressed one of my thesis’ research questions, I analyzed this statement independently. This in turn, left statement #7 to be analyzed independently as well.

4.4.4.1 #6. I consider the OWS program to be a good professional development opportunity. There were 26 responses ($M = 4.038, SD = 0.774$) indicating that teachers ‘agreed’ that the OWS workshops were a good form of PD.

4.4.4.2 #7. The OWS workshop presenters work in a manner that values collaboration between teachers and scientists. There were 26 responses ($M = 3.731, SD = 0.667$) indicating that teachers’ responses ranged from ‘undecided’ to ‘agreeing’ with this statement.
4.5 OWS Open-ended Questions

The open-ended workshop questions were administered at the same time as the OWS workshop surveys in the Phase II post. Two of the six questions selected focused specifically on influences on teachers’ practice and self-efficacy. The remaining questions were excluded as they looked at participants’ general comments regarding the workshops, pros and cons of the workshops, as well as influences on students’ learning. For the full list of questions see Appendix B.

4.5.1 #2. Has OWS influenced your teaching practice? If so, how? There were 25 responses with the following codes: yes-it has influenced; no-it has not influenced; and it has encouraged me to do more inquiry/hands-on/experiments. The findings are presented in Figure 13.

![Bar chart showing responses to OWS open-ended question #2.](chart)

Figure 13. Responses to OWS open-ended question #2.

The majority of respondents (80%) expressed that their teaching practice was influenced by the OWS workshops. For instance, Sylvia wrote “I liked the building project a lot. I use engineering challenges in my classroom and I learned how the scientist used vocabulary to build understanding and to review understanding before and after the challenge.” At the same time,
four respondents (16%) said that their practice was not influenced. Nine respondents (36%) said that they were influenced in terms of trying to implement more hands-on, inquiry teaching, or experiments.

4.5.2 #3. Has OWS had an energizing or confidence building effect? If so, how?

This question had 21 responses. The following themes emerged: *there was an effect on students; no; yes; and there was a feeling of enjoyment.* Results are shown in Figure 14.

![Figure 14. Responses to OWS open-ended question #3.](image)

Twelve respondents (57%) mentioned an influence on students. As one teacher wrote “Students **LOVE** hands-on activities and experiments and they gain confidence by ‘bouncing ideas’ off one another and ‘problem solving’ by incorporating all their ideas.” Additionally, four respondents (19%) said there was no effect and two respondents (10%) said that there was. Two respondents (10%) said they experienced a feeling of enjoyment during the workshops.

4.6 Interviews

Eleven teachers participated in semi-structured interviews. Interview prompts #8, #10, #12, and #13 were selected for data analysis as they were relevant to my study. The remaining questions generally probed teachers’ beliefs and approaches towards teaching and STEM
education, and so the responses were excluded from this analysis. The full interview protocol can be found in Appendix A. Codes were generated if at least two interviewees (18%) made reference to the same idea, thought, or opinion. After generating the codes, all of the transcripts were reread to explore responses that reflected any underlying themes that may not have fallen under the coding categories.

4.6.1 #8. How do you feel when you observe the OWS facilitators conducting inquiry workshops? Responses to question 8 yielded the following codes: *positive attitude towards presenter; learning/picking up ideas/approaches/activities; enjoying seeing the positive interactions between their students and presenter; commenting on presenters’ materials/resources/tools; and feeling confident/encouraged*. The results are presented in Figure 15 below.

![Figure 15](image)

*Figure 15. Responses to interview question #8.*

All eleven interviewees expressed having a positive attitude towards the OWS presenter. As Felix said:

I think it’s great that you have these people in the field doing the job, coming in to speak to the students. As a teacher, I can attempt to teach knowledge, but it is very difficult to bring in the practical experience into the school point. And it almost solidifies for the students that there is a reason why they sit here to do the
work, to take notes or do hands-on experiments that they can see, “okay there is a purpose.” Somebody who is in that field had to go through the same thing that they did to get there, and when the presenters came in, they brought... I think it was the way that they explained using the tools they had.

Furthermore, eight teachers (73%) mentioned learning new activities, approaches, or getting ideas from observing the presenter. For example, Theresa said: “…there is always something new that I learn from them.” Five teachers (45%) said that they enjoyed seeing the positive interactions of their students with the OWS facilitator. Felix also said that: “[he] was actually very impressed and happy with the presenters because they were able to engage the kids and speak to their level.” Six interviewees (55%) mentioned the resources and materials that the presenters brought. In Basia’s words: “…you want a lot of different ways of doing things in your class… and all those kinds of things are not available for you. And when the scientists come they bring actually everything with them.” Only Trey and Brandy (18%) mentioned feeling encouraged or confident from observing the OWS facilitator. Brandy said: “I feel encouraged. I’ve seen some great ones, and to be honest with you, I’ve learned different approaches that they’ve used...”

4.6.2 #10. Which OWS strategies, if any, have you tried to implement in your science or math classroom? I generated the following codes from my data analyses: hands-on/experiments; vocabulary activity; debrief/consolidation; re-enforcing what I’m already doing; and use of visuals. See Figure 16 for the results.
Figure 16. Responses to interview question #10.

Over half of the participants (64%) said they have tried to implement hands-on activities and experiments in their classrooms that were observed in the OWS workshops. Felix mentioned: “I like the experiments they did. It gave me some ideas, some of the hands-on stuff that were more complex or enhanced from what I’ve been giving the students.” Basia shared the following:

Yes, I did a lot. Last year we did the owl pellets, and I ordered them and I exactly did it with this year’s class. Exactly the same way as the scientists did and really it was successful. Definitely, they didn’t want to stop, I carried on for 4 days, or 5 days, because every day, one block, and it went very, very well, because step by step I was aware of what exactly to do. Like what kind of stuff I can do, step 1, step 2, step 3. Before also I was doing [things], but with scientists I got more ideas to add more stuff. They didn’t do one experiment only.

In addition, four participants (36%) mentioned replicating debrief and consolidation in their lessons. Trevor said: “The one I saw last year, you do that wrap up period, and try to pull it all together. I try to do that whether it’s math or science, actually at the end.” Ginny, Brandy, and Sylvia (27%) spoke about a vocabulary, word-wall activity they are trying to use in their classroom. Brandy said: “The vocab terms were placed on the board and kids were asked to link things to those different terms so that they are able to express their understanding of even the vocab terms, and I like that because generally I don’t necessarily explicitly teach the vocabs.”
Trevor and Ginny (18%) mentioned using visuals like the OWS presenters. Ginny said: “I like how whenever they talk about something they use the visuals, like a little piece of paper that has the word on it and they’ll put it on the board while they talk about it.” Finally, Leo and Felix (18%) said the OWS facilitators’ approaches re-enforced what they already do in their classrooms. In Leo’s words: “No, there wasn’t anything novel necessarily. Most of it was just reinforcing what I was trying to do, which is great.”

4.6.3 #12. Do you think you benefitted from the OWS workshops? If yes, how so (i.e., ideas, activities, content knowledge, pedagogical practices, etc.)? The following codes were generated: yes-I benefitted; ideas/strategies/practice; content knowledge; reaffirming/reinforcing the need for hands-on; seeing from a different perspective; and I would participate in an OWS workshop for teachers. Results are in Figure 17.

![Figure 17. Responses to interview question #12.](image)

All of the participants said they benefitted from the OWS workshops. Trey said: “I definitely feel that I benefitted from it. I would like to do it again. I would like to do more of them.” Seven teachers (64%) described these benefits in terms of getting ideas and strategies for their practice. In Ginny’s words: “…I would probably want to copy some of the stuff that they did in their workshops.” Leanne, Trevor, and Brandy (27%) said it reaffirmed or reinforced the need for hands-on, inquiry learning. Leanne said: “I think it just reinforced my
understanding of interesting science class.’’ Trey and Basia (18%) said they would participate in OWS workshops for teachers. As Basia put it: “I don’t mind, as a teacher, working with a scientist and having some workshops, not including students, but only the teachers and the scientists. We get kind of a training.” Theresa and Basia (18%) also said they benefitted from seeing something from a difference perspective. Theresa said: “Like I said, it’s so real world related, especially the perspective that I see presented, it’s tangential, and you get a different look at things that have you, yourself thinking.” Finally, Veronica and Ginny said they benefitted in terms of content knowledge. Veronica said:

Yeah, I think definitely. I think we do and I think the kids do for sure. How so? It’s nice to have a scientist come in too as a teacher that is self-teaching yourself some of these things. It is nice to hear someone explain it to you and sit there, almost like you are a student… it either says “okay, you’re on the right path,” or “okay, I need to look at that again.” Definitely, the ideas, the activities that they use, the knowledge. I think we talked about the practice of consolidating at the end is huge for the kids, instead of just letting them just walk away or not get anything out of it, but like I said, we have to do it a slightly different way.

4.6.4 #13a. Given the opportunity, how would you improve your science or math teaching practice? The following themes came up: by doing more inquiry/hands-on; I would need more prep time; I would need better access to and management of resources; and by attending more professional development. Results are presented in Figure 18.
Five participants (45%) said they would do more inquiry and/or hands-on teaching. In Leanne’s words: “Just keep increasing the number of hands-on activities that I’m doing with the kids.” Ginny also said:

So the way that I would improve it, I would incorporate more hands-on activities for sure. More hands-on stuff, less worksheets, less textbook, more hands-on things, more connecting to the big ideas, not just reading a piece of paper, and I think the avenue for doing that is just more resources. I just feel there isn’t really much emphasis on it. There’s no professional development for science ever, it’s always math or literacy.

Furthermore, five interviewees mentioned needing better access to and/or management of resources, materials, and equipment. As Trevor put it: “…to have enough equipment in order to actually... and having that equipment organized in the lab prep room and stuff like that, everything is ready to go, that would be great.” Ginny also has this to say:

It would be maybe nice if there were resources packages that we could buy that had pre-made little experiments that you could do with your class. Like a little set you could buy and “here’s a way to show how to teach this”. Honestly, when I taught science last year for 6 and 7, there was literally just the textbook and the teacher guide. So I feel School Boards need to put more emphasis on some of that stuff. At the same time, I’ve been in our storage room and there’s tons of
science stuff in there. There’s all the beakers and all that kind of stuff, but it just feels like so much prep. They need to make the prep part easier because we are busy people and we need some stuff ready to go sometimes. And so I think the prep, we need some help with that. Or at least more resources.

Four participants (36%) said they would attend more professional development related to teaching STEM subjects. Trey said: “…just receiving more professional development on it, whether it’s an AQ or taking anything with OWS kind of gives you a fresh perspective on things that kind of affects your teaching.” Trevor, Sylvia, and Felix (27%) mentioned needing more prep time to prepare better lessons. Trevor said: “If I was able to get more time to plan certain things, like a science team… it’s just time that’s a factor that teachers have.”

4.6.5 #13b. Can you describe the best avenue for such improvement and/or professional development? The themes coded for were: some form of workshops/PD; hands-on/’doing’ workshops/PD; workshops/PD provided/paid/in school; online workshops; OWS workshops; and learning from colleagues. See Figure 19 below.

![Figure 19: Responses to interview question #13b.](image)

Nine participants (82%) described some general form of PD or workshops as the best avenue for improving teaching and partaking in PD. As Brandy said: “But I think overall, it’s that learning piece that I need to implement which comes through either PD sessions, going to
workshops like these…” Leo, Veronica, and Felix (27%) agreed that workshops or PD should be focused on learning how to conduct specific hands-on activities. Veronica said: “I think when we’re doing professional development activities in the school, if we could definitely make it part of that, I think that would be worthwhile, because going and watching, but actually doing it yourself would be good.” Veronica, Leanne, and Trey (27%) said PD workshops should be provided or funded as part of the working school day. Leanne said: “Board-funded workshops would be fantastic… If it was paid for, that would be fantastic.” Five teachers (45%) mentioned the OWS workshops as an effective form of PD. Basia said: “These kinds of opportunities like OWS; we go and attend other workshops and work with other teachers and get to learn other person’s ideas…” Theresa and Trey (18%) spoke of the benefits of using online workshops. Trey commented: “Maybe you could offer an online module for people right now, I think that would be great.” Five participants (45%) said that informal, working with and learning from their colleagues was the best approach towards implementing new classroom practice. In Leo’s words:

I think one of the things that we can do is get together and work on a lot of simple experiments that would work and that would tie into some of the stuff that we’re doing that don’t involve a lot of set up, that don’t allow an awful lot of cleanup, because really now our periods are getting shortened by the second... Some of these quick and dirty ones, we can’t even make it through the period. I think what we need is those quick ones that are useful. The PD session hands-on for us as well would be great. Talking about how integrating the curriculum in different ways will be great. All those kind of things.

4.7 Chapter Summary

This fourth chapter has presented the findings of my study, and yielded both anticipated and unanticipated results. For the most part, teachers felt they gained new ideas from the OWS workshops, which aligned with my prediction. Yet, when the teachers in my study were asked
if their pedagogical approaches were affected, the responses were split. In addition, participants generally reported that neither their STEM content knowledge nor their self-efficacy in teaching STEM were influenced. As mentioned earlier, it is worth noting that because teachers were observing vicarious social models, there may be a delay between the observed behaviours of the OWS presenters and teachers subsequently implementing these strategies in their practice (Masia & Chase, 1997). As a delayed form of vicarious learning, the teachers might begin employing some of the observed pedagogical approaches after taking part in post data collection. That is, teachers may report that currently they do not employ integrated and inquiry-based STEM teaching any more than they did prior to participating in OWS. Hence, long-term observation of my participating teachers’ practice could yield differing findings. In addition, forty-five percent of interviewees also indicated that they considered the workshops as a potential source of PD. I now expand on these findings with a discussion of the results in the following chapter.
Chapter 5: Discussion and Conclusions

This fifth and final chapter presents a discussion of my findings, limitations of my study, and the implications of my research work. This will be followed by an overall summary of my study and closing remarks. The findings’ analysis will be framed in terms of my research questions in addition to the recurring themes presented in this thesis. Recall that the purpose of this study is to explore whether teachers’ participation in science, technology, engineering, and mathematics (STEM) outreach workshops affects their professional practice and self-efficacy. To this end, I re-visit the following four research questions:

- Can teachers’ participation in the OWS workshops increase their content knowledge, and if so how?
- Can teachers’ participation in the OWS workshops increase their confidence, and if so, how?
- How do OWS workshops provide teachers with a repertoire of new pedagogical approaches?
- Can the OWS workshops provide a viable source of professional development, and if so, how?

I will look at each of these four research questions individually. In addition, I note and discuss the following recurring themes that emerged from my analyses: the need for STEM literacy, under-preparation of STEM teachers, misunderstandings of authentic inquiry, as well as the relationship between self-efficacy beliefs and how they affect teachers’ practice. The latter two themes are interwoven into the discussion of the aforementioned research questions, while under-preparation of STEM teachers is analyzed on its own and the need for STEM literacy is discussed in the closing remarks.
5.1 Increasing Content Knowledge

There was no overall trend demonstrating an effect on participating teachers’ STEM content knowledge. In question #5 of the teacher reflections, only 4 of 10 (40%) participants reported that their content knowledge (CK) was affected. At the same time, the teachers who reported feeling that their CK was either not influenced or that they already possessed this CK, also combined for four respondents (40%). Likewise, on statement #2 of the OWS workshop survey, teachers varied between ‘undecided’ and ‘agreeing’ with the statement that the workshops contributed to their STEM CK. Furthermore, when asked about the benefits of OWS in interview question #12a, only 2 of 11 teachers (18%) said they were influenced in terms of CK. These findings suggest that participants’ beliefs are divided regarding whether or not OWS has affected their CK. Hence, I conclude that there was no overall trend for teachers’ CK to have been influenced by the OWS workshops.

In comparison, Nadelson, Seifert, Moll, and Coats (2012) conducted a study measuring the impacts on teachers from a STEM summer institute where teachers also participated in completing hands-on lab activities. Their findings revealed that teachers’ STEM CK was significantly impacted during the institute. However, unlike my study, the summer institute was an intensive four day program that incorporated other professional development (PD) elements as well. In another study, Zhang, McInerny, and Frechtling (2010) explored a teacher PD program delivered by university STEM faculty, as opposed to education faculty or school board mandated instructors. Although the study found that teachers’ STEM CK was influenced when taught by STEM faculty, they reported being surprised to find that in some cases, teachers learned more pedagogical approaches than they did CK. The OWS presenters in my study were not university faculty, but STEM professionals with research backgrounds. Although
participants were not influenced in terms of CK, there is still potential for acquiring pedagogical knowledge. As will be discussed below, this provides PD value for the OWS workshops.

Data from the OWS workshop observations showed that teachers did not participate in the workshops to the degree that I had expected. That is, they were mostly passive observers; frequently preoccupied with their own work. I was surprised to find that the general trend was for teachers not to exhibit the behaviours listed in the workshop observation checklist (Appendix C). Although these observations came as a surprise, upon closer inspection, the findings are to be expected. As discussed in Chapter 2, many STEM educators are either unprepared to teach integrated STEM content or do not have a thorough understanding of authentic inquiry (Marrero, Gunning, & Germain-Williams, 2014). In my study, this was evident from the observations that none of the teachers integrated STEM content nor connected any of the activities to STEM careers during these workshops. Furthermore, only two teachers promoted inquiry learning with their students (see Table 5). For instance, I observed these two teachers actively involved in the students’ activities, engaging in conversations, and asking students thought provoking questions to guide their learning, as opposed to simply sitting at their desks. In addition, only one teacher attempted to integrate technology and promote students’ 21st century learning skills (see Table 5), during the workshops. This teacher prepared an online evaluation tool for students to complete at home after the workshop to extend their learning. He was also involved in discussions with his students about the real-life applications that stemmed from the activities the students were doing.

Although about half of the teachers assisted with facilitation, much of the remaining time was spent by teachers simply observing in a withdrawn manner or completing unrelated work. In order for teachers to effectively assist their students through facilitation, teachers need to first garner a conceptual understanding of the content being explored in a given activity. Once the
teachers have the necessary content knowledge, it is more likely that they will be able to guide students through a topic so as to lead students to an understanding of concepts rather than simply providing answers. These findings regarding low teacher involvement in the workshops can be expected, as many teachers are unfamiliar with genuine inquiry or how to integrate STEM content.

This lack of active involvement in the OWS workshops could contribute to the finding that there were no significant influences on teachers’ STEM CK. As Supovitz and Turner (2000) point out, teachers need to be actively immersed in their PD to attain the most benefits. I was surprised to find that teachers did not play a more active role in the workshops, as there is support for the fact that teachers enjoy such active participation (Kelter, Hughes, & Murphy, 1992). To sum up, I anticipated that participating teachers’ CK would be affected, but this was not the case. Teachers mostly participated as passive observers, but that is to be expected as this study is attempting to observe effects on teachers’ practice that is not already commonplace. That is, because teachers are not frequently doing integrated, inquiry-based STEM teaching, it would be unreasonable to suddenly expect them to do so during the workshops. It is my hope that the OWS workshops can serve as a means of promoting STEM teaching strategies and make them more commonplace. The next section examines effects on teachers’ confidence and self-efficacy.

5.2 Increasing Confidence

Similar to the previous research question, there were no significant influences on teachers’ confidence in teaching STEM. Findings from the Teacher Efficacy and Attitudes Towards STEM (T-STEM) (Friday Institute for Educational Innovation, 2012) surveys indicate that there was no change in participants’ confidence and self-efficacy. Specifically, teachers’ responses to the Science Teaching Efficacy & Beliefs (STEB) scale showed that on average,
participants ‘agreed’ that they already have the confidence and abilities to effectively teach STEM subjects ($M = 4.003, SD = 0.5112$). Although this lack of significant change was also unexpected, these results suggest that the teachers in my study already have high efficacy beliefs. This conclusion is consistent with findings from other studies (Moseley, Bilica, Wandless, & Gdovin, 2014). Additionally, responses to question #4a in the teacher reflections also revealed that teachers were divided on the issue of whether their confidence and motivation were affected by OWS. Likewise, statement #5 from the OWS workshop survey found that teachers were ‘undecided’ about whether OWS had increased their confidence in teaching STEM ($M = 3.192, SD = 0.801$). Finally, only 2 of 11 (18%) interviewees mentioned that their confidence was affected in interview prompt #8. OWS open-ended question #3 also asked participants whether OWS had an energizing or confidence building effect. However, 57% of teachers described effects on their students as opposed to themselves.

Overall, I surmise that teachers’ confidence and self-efficacy were not influenced by the OWS program. Although I had anticipated the opposite results, two potential explanations for these findings have come out of the data. Firstly, like in the aforementioned findings for CK, the OWS workshop observations have shown that teachers did not get actively involved in the workshops. This lack of involvement by teachers could limit the effectiveness of any impacts the workshops otherwise may have had (Supovitz & Turner, 2000). Secondly, T-STEM survey data revealed that teachers ‘agreed’ that they possessed the confidence and abilities to teach science and math effectively. Thus, if teachers already have high self-efficacy beliefs it may be unreasonable to expect that these beliefs can be increased even further. Duran, Ballone-Duran, Haney, and Beltyukova (2009) conducted a similar study measuring the influences of a PD program on K-3 teachers’ self-efficacy and beliefs around inquiry-based teaching. They describe their findings in terms of the ‘ceiling effect’, specifically stating that because teachers
already described possessing high efficacy beliefs, these beliefs were not increased further by the PD program. I posit that the ceiling effect could also potentially account for my findings. Also, these findings beg the question of whether two half-day workshops are enough for effective PD. We know that sustained PD is more successful with the potential to enhance teacher learning and praxis (Pedretti & Bellomo, 2013).

In essence, the finding, that teachers’ confidence and self-efficacy were not influenced, relate to a recurring theme in my thesis regarding the relationship between self-efficacy beliefs and teachers’ practice. As has been demonstrated in Chapter 4 and will be discussed below, teachers’ instruction was not affected over the course of the study. Given the lack of change in participants’ self-efficacy beliefs as mentioned above, it would stand to reason that teaching practice would likewise remain unaffected in light of this theme. That being said, teachers reported on the Science Instruction (SI) scale of the T-STEM that they implement inquiry-based teaching only ‘about half the time’ (\( M = 3.173, SD = 0.622 \)), despite ‘agreeing’ that they had the confidence and efficacy to teach STEM effectively. In contrast to my findings, “Teachers with a high sense of efficacy are more likely to utilize student focused or inquiry-based lessons” (Luera & Otto, 2005, p. 249). Thus, my findings suggest there are other factors at play that may be hindering teachers’ abilities to implement more hands-on, inquiry-based teaching. Some of these potential factors are explored below.

### 5.3 Providing a Repertoire of Pedagogical Approaches

The findings for this research question were mixed. As mentioned earlier, teachers’ responses indicated on the SI scale that they implement hands-on, inquiry-based teaching ‘about half the time’ (\( M = 3.173, SD = 0.622 \)). Furthermore, the Generalized Estimating Equations (GEE) analysis of the SI scale findings showed no statistically significant change in teachers’ instructional practice. Thus, I conclude that even after participating in the OWS workshops,
teachers still implemented inquiry-based, hands-on teaching only about half the time. There was however, a strong trend in responses that OWS has provided participants with new ideas and activities for their teaching. On question #3 of the teacher reflections, 7 of 10 teachers (70%) said they gained new ideas when asked if the OWS program had influenced the way they teach science and/or math. However, when asked about influences in terms of pedagogical approaches, in question #4b of the teacher reflections, 5 of 9 respondents (56%) wrote that they were either not influenced or that they already knew these strategies. Only the remaining four teachers (46%) responded that they did gain new ideas. In addition, the OWS workshop surveys also had mixed results. Teachers ‘agreed’ that they obtained new ideas from OWS on question #1 ($M = 4.077$, $SD = 0.484$). At the same time, participants’ responses ranged from ‘undecided’ to ‘agreeing’ when asked in question #10 if OWS has influenced them in terms of pedagogical approaches ($M =3.654$, $SD = 0.797$). In the ensuing OWS open-ended questions, on question #2, 80% of teachers (20 of 25) reported that OWS has influenced their practice. Only 4 of the 25 (16%) responded that their practice was unaffected. Nine (36%) of the 80% who reported that their practice was affected said that they were influenced in terms of desiring to implement more hands-on, inquiry-based teaching. Finally, the interviews were quite telling as well. When asked how interviewees felt observing the OWS presenters conducting the workshops (interview prompt #8), 73% (8 of 11) said they learned or picked up new activities and ideas. Additionally, when teachers were asked about any benefits gained from participating in the workshops in prompt #12, 64% (7 of 11) responded that they benefited in terms of ideas, strategies, or practices.

As I anticipated, there is ample evidence that participants felt they acquired new ideas for teaching STEM. In their study of an outreach STEM program for girls, Dubetz and Wilson (2013) describe the benefits for teachers involved; that teachers were able to take activities
learned and implement them in their own classrooms. This is also consistent with findings from Lott’s (2003) study, whereby teachers also gained new teaching ideas from a science outreach workshop. On the other hand, teachers’ reported that instructional practice did not change significantly as they continued to implement hands-on, inquiry-based teaching ‘about half the time’ as per the T-STEM SI scale. Also, teachers were fairly evenly split when asked if they were affected in terms of pedagogical approaches. In sum, while I expected teachers to gain new ideas, I had also expected that teachers’ pedagogical approaches would be influenced in addition to their implementation of these approaches. This suggests an area of improvement for teachers, and is consistent with the literature that the use of inquiry-based teaching methods by STEM teachers is not yet commonplace (Sanders, 2009).

It seems that much more needs to be done in order to specifically affect teachers’ pedagogical approaches, content knowledge, and self-efficacy. If this learning of new ideas experienced by the teachers was channeled in a constructive way, there could be interesting possibilities for employing such workshops as formal teacher PD. I hypothesize potential explanations for why these workshops were not very successful in terms of influencing teachers’ instructional approaches and content knowledge. These explanations include: ambiguous terminology, lack of resources and confusion surrounding the meaning of inquiry.

5.3.1 Ambiguous terminology. Firstly, I found it interesting that teachers expressed they gained new ideas but not necessarily new pedagogical strategies from the workshops. Upon first glance, I thought these findings to be contradictory, but I feel I may be partially at fault for not providing clearly defined terms. Specifically, ‘pedagogical approaches/strategies’ can have different meanings for different people. So while I assumed that ‘new ideas’ could mean anything from new activities, new strategies, new approaches, etc., I had not explicitly defined what I meant by new ‘pedagogical approaches/strategies’. This was a shortcoming on
my part, in that I subconsciously equated new ideas with new pedagogical approaches. Upon deeper analysis and interpretation of the findings, I have gained an overall sense that teachers associated the terms ‘pedagogical strategies/approaches’ with a more general, practical framework for teaching as opposed to specific activities or strategies. More clearly defined terminology could have avoided this confusion; and so in future research I will be more mindful to make clearer distinctions. Future explorations that more accurately define these terms might yield clearer findings.

5.3.2 Lack of resources. Secondly, I propose resource limitations as a potential deterrent to teachers’ abilities to conduct inquiry-based STEM teaching. Limited access to the necessary resources could account for why teachers’ actual implementation of instructional practices did not change, despite the general trend that teachers gained new ideas and a desire for inquiry-based learning from the workshops. In question #4 of the OWS workshop survey, participants were just shy of ‘agreeing’ that OWS workshops were capable of providing inquiry-based investigations beyond what teachers were able to do in their own classrooms. Although the question did not probe why teachers felt this way, one possibility is a lack of resources that OWS has access to. This is supported by 55% of interviewees (6 of 11) who made reference to the OWS facilitators’ advantageous materials and resources when asked how they felt when observing the facilitators conducting the workshops in prompt #8. Additionally, in interview question #13a, five interviewees (45%) said they would like to improve their teaching practice through better management of and/or access to resources. Taken together, these findings share a common theme; at least some portion of teachers in my study feel they are limited by a lack of resources. This in turn could help explain why teachers’ instructional practice had not changed over the course of the study, despite teachers’ acquisition of new teaching ideas.
5.3.3 Confusion surrounding inquiry. The third potential explanation for why teachers felt that OWS was able to carry out inquiry-based STEM activities beyond what they were able to do in their classrooms could simply be due to a misunderstanding of inquiry. This reoccurring theme in my thesis is consistent with the literature that was explored in detail in Chapter 2 (Capps & Crawford, 2013; Marshall, Horton, Igo, & Switzer, 2009; Marrero, Gunning, & Germain-Williams, 2014). At first glance, this is contradictory to participants’ generally high efficacy beliefs, as per findings of the T-STEM STEB scale. That is, teachers ‘agreed’ that they had the confidence and abilities to teach STEM subjects. However, this could simply mean that teachers feel confident in teaching the stand-alone STEM subjects, but not necessarily in an integrated and inquiry-based manner. Many STEM educators report feeling that they teach STEM effectively despite mostly employing traditional, didactic approaches that neither integrate nor include hands-on inquiry. Furthermore, similar studies that examined teachers’ knowledge and beliefs surrounding inquiry found that even teachers skilled at teaching in an inquiry-based way had diverse conceptions and understandings of what genuine inquiry looks like (Ireland, Watters, Brownlee, & Lupton, 2012; Tseng, Tuan, & Chin, 2013). The various perspectives and understandings of inquiry that exist add to the confusion. A teacher who is less experienced in inquiry teaching would have to navigate these multiple conceptions and understandings of what inquiry is, before becoming proficient at employing such teaching approaches. Thus, it is my understanding that even teachers who report high self-efficacy beliefs in teaching STEM content may not necessarily be skilled in integrating these subjects, implementing inquiry-based teaching, nor be able to easily acquire these skills.

In sum, the OWS workshops were effective in providing teachers with new ideas for teaching STEM. However, at this point in time, I have not observed any influences on teachers with regards to pedagogical approaches and increased implementation of inquiry-based
instructional practices. Anderson and Helms (2001) as well as Tseng, Tuan, and Chin (2013) provide a list of further limitations that hinder teachers’ ability to increase the use of such pedagogy in their practice. These include insufficient teaching time, tensions between curriculum standard ideals and classroom reality, as well as concern over adequacy of effectiveness of reform-based teaching methods. These limitations go beyond a simple lack of resources or misunderstanding of inquiry, revealing that there are many more complicated factors at play. Because educational reforms call for a STEM education that is integrated and inquiry-based, this could shed light on why such a form of STEM is not yet commonplace in classrooms. In light of the potential explanations I outline in my study, a deeper exploration into these limitation could be of explanatory benefit.

5.4 Viability of OWS as a Source of Professional Development

On statement #6 in the OWS workshop survey, the teachers ‘agreed’ that the workshops served as a good PD opportunity ($M = 4.038, SD = 0.774$). On interview prompt #13b, five teachers (45%) made mention of OWS workshops when asked about best avenues for PD. As mentioned above, in question #2 of the OWS open-ended questions, 80% of the teachers (20 of 25) reported that OWS has influenced their practice. In addition to the aforementioned findings (that the majority of teachers gained new teaching ideas from OWS), these results suggest that the OWS program could indeed be an effective form of PD. Although the workshops did not have the expected influences in terms of CK and self-efficacy, I believe there can still be merit in a form of PD that provides teachers with new teaching ideas. As was discussed above, a study by Zhang, McInerny, and Frechtling (2010) demonstrated the potential of STEM faculty-led PD to have a greater effect on teachers’ pedagogical knowledge than CK. Thus, it is reasonable to observe teachers benefitting in terms of pedagogical activities, even if they were not necessarily influenced in terms of CK.
According to Brand and Moore (2011), teacher PD that whose goal is to promote unguided pedagogy should itself be taught in an unguided model that actively engages participants. And as Luera and Otto (2005) point out, “teachers teach as they were taught” (p. 243). Consistent with the claim that teachers learn vicariously, the OWS program creates an opportunity for teachers to explore and conduct hands-on, inquiry activities that they can later bring to their students. Such a form of PD should also be sustained over a duration of time, as well as incorporate practice and reflection of the ideas learned. In my study, teachers had the chance to participate in two OWS workshops per year, for a total of four workshops throughout the duration of my study. However, in my project the OWS workshops were not intentionally framed as PD for teachers. Hence, they did not incorporate conscious practice and reflection for teachers, thereby limiting the PD potential of the OWS workshops. Although my study involved open-ended reflection questions, these were not administered in association with teachers attempting integrated STEM or inquiry-based strategies observed from OWS. While there was potential for reflection, it took place after the fact and so its PD benefits were not as effective. That being said, OWS was successful in delivering new teaching ideas in a way that educators could model for their students beyond the workshops.

As mentioned earlier, in a study by Nadelson, Seifert, Moll, and Coats (2012), teachers’ STEM CK was significantly influenced by a STEM summer institute. The summer institute PD in their study was an intensive four day program that also involved additional PD elements. Thus, if the OWS model could be improved upon to include other PD elements such as regular practice, reflection, and collaboration, I believe it could serve as an even more effective form of PD.

From the OWS workshop observations, I felt that the OWS presenters and workshops combined for an effective source of modelling integrated STEM content, taught in an inquiry-
based way. Hence, I believe it was reasonable to expect teachers to be affected. A few of the workshops fell short in assessment and technology integration, which, although important for integrated hands-on STEM teaching, is not directly related to my research questions and is beyond the scope of my study. Overall, these findings affirmed the effectiveness of the presenters. This was anticipated, as the level of students’ engagement was generally very high and, for the most part, the activities differed greatly from traditional science or math lessons.

From the workshop observations, I found that the grade 8 Life Systems workshop was the only one that was not so effective. Students were provided with the answers from the beginning. They received ready samples, were told what they should find under the microscope, and then were asked to draw/record these same elements once found. Such factual knowledge should at least foster opportunities for thoughtful questioning. Unfortunately, such questioning did not take place in this workshop. In addition, problem solving or practicing of 21st century learning skills were also absent from this workshop.

Fortunately, the remaining seven workshops did give students a chance to ask thoughtful/profound questions and make independent decisions to solve problems. Overall, the OWS presenters were skilled, knowledgeable, and implemented inquiry-based, integrated STEM learning activities. The evidence suggests that the OWS workshops and the OWS presenters combine for an effective model of STEM teaching and learning.

Morrison and Estes (2007) explain that having scientists engage teachers in inquiry investigations is an important element of effective PD. This collaboration of teachers and scientists promotes an environment similar to that in which scientists work and discover knowledge. I posit that this in turn may help teachers replicate that similar environment of scientists’ work and discovery for their own students. However, Morrison and Estes go on to say that “teachers’ lack of comprehension about what science is and how it is conducted by
scientists may hinder collaboration between scientists and teachers” (p. 166). Such a hindrance explains at least in part the teachers’ lack of active participation in the OWS workshops that was discussed above.

On statement #7 of the OWS workshop survey, the teachers’ responses ranged from ‘undecided’ to ‘agreeing’ \((M = 3.731, SD = 0.667)\) that the OWS presenters worked in a manner that valued collaboration between the presenters and the teachers. Although Powell-Moman & Brown-Schild (2011) report that there are benefits to PD models that involve teacher and scientist collaboration, this type of teacher PD is not yet commonplace and so both teachers and OWS presenters may be unfamiliar with the model (Trautmann & MaKinster, 2005). Arguably, without the conscious knowledge of such PD potential, teachers and presenters may be unknowingly limiting the number of effective interactions that would facilitate beneficial collaboration and learning. Thus, while I believe that the OWS presenters served as an effective model for teachers, future work on improving collaboration between teachers and STEM professionals may yield more significant impacts. This could be made possible by informing teachers of such an expectation prior to the workshop, and opening a line of communication with teachers ahead of time to better prepare them for what to expect during the workshops.

Indeed, Krasny (2005) suggests that PD programs whereby teachers are involved in their own, on-going construction of knowledge are more effective in bringing about long-term changes to practice. Although my study did not involve a formal PD element that teachers were involved with in relation to the workshops, the multiple opportunities to participate in the workshops over the course of the study simulated these conditions.

However, we do know that one-off half-day workshops are not enough for effective PD, and that sustained PD is more successful (Pedretti & Bellomo, 2013). Furthermore, Pedretti and Bellomo (2013) go on to say that teachers working together in a PD context (professional
learning communities) is much more effective than teachers working in isolation. The social aspect of working and learning together in tandem with the mutual support of colleagues promotes the creation and distribution of knowledge amongst those involved. A future study could have teachers actively involved in these workshops and collaborating in professional learning communities, all over a sustained period of time, in order to measure subsequent impacts.

5.5 Under-Preparation of STEM Teachers

This theme ties into the aforementioned analysis of confusion surrounding the term inquiry. Many teachers lack understanding about what it means to teach in a manner that is in line with authentic inquiry (Capps & Crawford, 2013; Marshall, Horton, Igo, & Switzer, 2009; Marrero, Gunning, & Germain-Williams, 2014). A positive finding in my research was that teachers reported on the T-STEM survey that they possess high efficacy for teaching STEM subjects. That being said, even if teachers are prepared to teach the individual STEM subjects in a ‘traditional’ teacher-centered approach, educators may be under-prepared to engage their students in genuine inquiry. This could possibly explain the findings in my study, that teachers did not demonstrate an increase in implementation of hands-on, inquiry-based teaching strategies. From Tseng, Tuan, and Chin’s study:

…experienced science teachers’ suggestions to beginners for implementing inquiry teaching were to watch concrete demonstrations from instructors or other teachers, experience inquiry activities by themselves, construct their own beliefs of inquiry and inquiry teaching, and review literature on inquiry and inquiry teaching. (2013, p. 821)

This finding from their study leads me to suggest that by engaging in the OWS workshops and taking an active role in trying out the hands-on, inquiry teaching activities, teachers will be able to beneficially impact their implementation of their own inquiry-based teaching methods. The
suggestions from Tseng, Tuan, and Chin offer support for potentially utilizing OWS workshops as a form of teacher PD and appropriate vicarious learning.

5.6 Limitations

5.6.1 Missing data. A major limitation of my study was missing data in the T-STEM surveys. It was quite difficult to catch all of the teachers at all three points in time when the T-STEM surveys were being administered at a given school. Hence, there are significant fluctuations in the numbers of responses from Phase I, Phase II pre, and Phase II post. Consequently, a GEE was used for statistical analysis as it permitted for partial dependency resulting from my missing data. A more complete data set would allow for more accurate tracking of participants’ responses to the STEB and SI scales on the T-STEM survey. This would offer a more precise image of how teachers’ confidence and self-efficacy as well as implementation of hands-on, inquiry teaching was affected over time. In addition, due to this missing data, demographic information was not available for all participants. It would have been interesting to compare the effects of the OWS workshops on the content knowledge of novice versus veteran teachers.

Also, teacher practices were self-reported. It would have been helpful and insightful to spend time in a few classrooms to observe STEM lessons. These sorts of observations would provide valuable first-hand knowledge of teachers’ practice from a third-person perspective. This would have been especially informative given the aforementioned confusion surrounding integrated and inquiry-based STEM education. That is, participants may or may not be implementing such teaching practices, but mistakenly reporting the opposite.

5.6.2 Lack of active participation in the workshops. A second limitation in my study was a lack of active participation in the workshops by most teachers. I was surprised to observe
this trend given Kelter, Hughes, and Murphy’s (1992) findings that teachers enjoyed actively participating in workshops. While conducting workshop observations, I found it hard not to get engaged in the activities that students were doing. That being said, it should be noted that the workshops were designed for the students and not for teacher PD. The teachers that did not actively participate were probably utilizing the time made available by the presence of the OWS presenters leading the class, in order to get ahead in their own work (marking, lesson planning, etc.).

5.7 Implications

As I conclude this thesis, there are four key implications that emerge from my findings. The first being that there is a continued misunderstanding of integrated, inquiry-based STEM education. Policy makers and administrators should work towards establishing norms of what genuine, authentic inquiry entails, as even teachers experienced in doing inquiry-based instruction hold varying concepts of the term (Ireland, Watters, Brownlee, & Lupton, 2012; Tseng, Tuan, & Chin, 2013). As also discussed above, there can be multiple factors that hinder teachers’ implementation of hands-on, inquiry-based teaching (Anderson & Helms, 2001; Tseng, Tuan, & Chin, 2013). In my study, teachers reported employing authentic inquiry teaching only ‘about half the time’, despite demonstrating high beliefs in their confidence and efficacy to teach STEM subjects. From this finding, I conclude that while the teachers in my study felt effectively prepared for teaching stand-alone STEM subjects, they may be under-prepared to integrate the subjects and offer more inquiry-based pedagogy. In Chapter 2, I discuss the recognition of integrated, inquiry-based STEM education as the way to move forward for teaching students these subject areas. In light of this, teacher pre- and in-service training has to do more to prepare teachers for implementing genuine inquiry as well as integrating the STEM strands. Earlier in this chapter, I presented one such approach in the
engaging of pre- and in-service teachers in actually ‘doing’ integrated, inquiry activities as part of their development, instead of just learning ‘about’ them (Brand & Moore, 2011; Luera & Otto, 2005). In addition, teachers need the resources and curriculum content to support such teaching.

Secondly, because the majority of teachers expressed that the OWS program served as a good PD opportunity and that they gained new teaching ideas, I recommend its use (with some modifications) as a formal teacher PD initiative. In my study, the OWS program failed to influence teachers’ content knowledge, self-efficacy, and implementation of more inquiry-based teaching. However, I argue that if the OWS program incorporated other PD elements such as practice, reflection, and collaboration over sustained time, it has the potential to affect teachers’ content knowledge, self-efficacy, and implementation of inquiry pedagogy. Recall the Nadelson, Seifert, Moll, and Coats study (2012), in which the researchers provided a summer institute. In their model, they were able to engage teachers in hands-on inquiry, enhance teachers’ content knowledge, and incorporate ‘successful’ PD elements. I feel confident saying that OWS has similar potential.

Thirdly, the OWS program can be of great benefit for students of lower socio-economic status (SES). As mentioned in Chapter 2, outreach programs can be an effective means for helping bridge the achievement gap between students of low versus middle, and high SES by providing more opportunities to bring lower-SES youths towards success (Rahm, Martel-Reny, & Moore, 2005). My study took place in schools of lower-SES, and teachers described the OWS as having an influence on students. The workshop observations would also suggest a beneficial impact on students. Hence, in addition to the OWS program’s PD potential, it can also serve to help bridge the achievement gap for youth of differing SES classes.
Finally, as was mentioned earlier, STEM education is not formally mandated in the Ontario science and technology curriculum. Thus, Sander’s (2009) “business as casual” observation regarding STEM education is to be expected in the province of Ontario as teachers are not formally required to teach following an integrated and inquiry-based STEM model. The Ontario curriculum does however include the Science, Technology, Society, and the Environment (STSE) model, which similarly to STEM education has as its goal to promote scientific literacy and student interest in science and technology (Ontario Ministry of Education, 2007; Pedretti & Nazir, 2011). However, STSE education aims to do so by presenting science and technology with a more humanistic perspective and its reciprocal relationship with society and the environment. Although Pedretti and Nazir describe several currents in STSE education, throughout these currents there are several parallels with integrated and inquiry-based education. These include: inquiry-based learning, integration of science and technology, and 21st Century Learning skills such as problem solving and decision-making. As STSE education already forms part of the Ontario science and technology curriculum, it is worth considering whether it would be possible to incorporate the subjects of engineering and mathematics as well. If this were indeed possible, then there is an increased likelihood that integrated and inquiry-based STEM education would become more prevalent in Ontario classrooms.

5.8 Areas for Future Research

In this section I suggest some interesting questions for future exploration that have come out of my study’s findings, limitation, and implications. First, I think it would be worth replicating the study with similar conditions in order to measure influences on teachers, while framing the OWS program as a deliberate form of PD for teachers. That is, to inform teachers of the expectation for them to be actively involved in the workshops while at the same time adding other PD elements such as practice, reflection, and collaboration. It would also be
interesting to compare whether such a form of PD would have a greater impact on teachers working in lower-SES schools in comparison to traditional, didactic-style PD. Furthermore, I would specifically like to ask teachers what was limiting their implementation of inquiry-based teaching to only ‘about half the time’, i.e., lack of resources, time, activities, etc. In addition, I believe it would be advantageous to obtain more complete data so as to have a clearer picture of any trends based on teacher demographics, as well as how teachers responded over time. I believe it would also be worthwhile to perform long-term observations of participating teachers’ practice, so as to account for the possible delay in vicarious learning.

Moreover, it would be interesting to examine the demographic data of my respondents to compare whether there were any patterns between those teachers whose content knowledge (CK) was affected versus those whose was not. For example, maybe novice teachers felt their content knowledge had improved while veteran teachers felt it had not or vice-versa. For instance, Monica, who was a teacher reflections respondent, was in her first year of full-time teaching, reported that her CK was not affected. It would be interesting to explore whether this is a common trend or an anomaly. In their study of the impacts of a PD program focused on increasing self-efficacy for teaching inquiry, Powell-Moman and Brown-Schild (2011) found that the longer a teacher had been teaching, the less time they spent implementing inquiry-based ways of teaching. By the same token, it would be interesting to explore if any influences on teachers’ CK were correlated with years of teaching experience. Unfortunately, this demographic data was not available for all of the participants at this stage of data collection, but could offer an interesting area of future research.

Finally, as mentioned above, I was concerned about the problematic usage of the terminologies ‘pedagogical approaches/strategies’. I considered new ideas, activities, strategies, etc. learnt to be ‘pedagogical approaches’, however, I did not provide my participants with the
same definitions. Indeed, this resulted in mixed findings, whereby many teachers responded that their pedagogical approaches were not influenced, even though the vast majority reported gaining new teaching ideas. Clarifying terminology could provide clearer results in future studies.

5.9 Closing Remarks

The findings of my study revealed both anticipated and unanticipated results. Unanticipated were the findings that teachers were not influenced in terms of their content knowledge, confidence, or pedagogical approaches. I argue that the lack of any effects on teachers in these areas could potentially be caused by the following: lack of teachers’ active involvement in the OWS workshops, pre-existing high efficacy beliefs, a vagueness regarding the term ‘pedagogical approaches’, teachers’ misunderstandings of inquiry, and teachers’ resource limitations. Conversely, the anticipated results suggest that the vast majority of participants learned new ideas for their practice and considered the workshops to be an effective form of PD. From observing the OWS workshops, I found the presenters as well as the activities and content to be very effective in terms of integrating STEM content in addition to presenting authentic inquiry opportunities.

Furthermore, I posit that my study hints at the continued need for STEM literacy. These teachers welcomed the OWS presenters into their classrooms to teach something new to their students. The teachers considered the OWS program to offer some new learning that students would not have otherwise received. If teachers did not consider OWS to be a valuable STEM learning experience, they would not have dedicated the time (and resources) to bring them in. This underlines the need for students to learn certain STEM skills that are not normally being taught in STEM classrooms.
As a STEM educator, this study has shown me the intricacies of implementing integrated and inquiry-based STEM education. It has also shed light on the complexities of teacher PD and on some potential avenues for maximizing benefits from PD. I am content that the teachers in my study considered the OWS program to be a good source of PD, and that they gained valuable teaching ideas from my study. I hope that my work can in some small way contribute to further improving teachers’ practice, PD, and STEM education as a whole.
References


President’s Council of Advisors on Science and Technology (U.S.), & United States. Executive Office of the President (PCAST). (2010). *Report to the president, prepare and inspire: K-12 education in science, technology, engineering, and math (STEM) for America’s


Appendices

Appendix A. Semi-structured interview protocol

Interview # _______ Date: _______________ School: _______________________________
Name: _______________________________ 
OWS Workshop Attended: _______________________________ 
Grades Taught: _______________ Educational Background: _______________________________

1. Can you describe your philosophy of teaching?

2. How do you approach teaching science/math/technology?

3. a. What is your understanding of STEM?
   b. Do you feel this is a feasible for teaching science/math/technology? Why?

4. How do you feel when you are teaching science/math/technology (i.e. Confidence, ability, self-efficacy, etc.)?

5. Do you feel that your ability to teach science/math/technology affects and/or impacts your students’ ability to learn science? Explain.

6. Describe to me a science lesson in your science class.

7. a. Have you incorporated inquiry oriented activities in your classroom thus far this year?
   b. If so, can you describe these activities?

8. How do you feel when you observe the OWS facilitators conducting inquiry workshops?

9. a. How would you describe your experience with the OWS workshops?
   b. Your students’ experience?

10. Which OWS strategies, if any, have you tried to implement in your science classroom?

11. Please comment on your experiences while implementing OWS activities in your classroom in terms of:
   a. Successes
   b. Challenges

12. a. Do you think you benefitted from the OWS workshops?
   b. If yes, how so (i.e., ideas, activities, content knowledge, pedagogical practices, etc.)?

13. a. Given the opportunity, how would you improve your science teaching practice?
   b. Can you describe the best avenue for such improvement and/or professional development?

Thank You!
Appendix B. Outreach Workshops in STEM (OWS) open-ended questions

**Outreach Workshops in STEM (OWS) open-ended questionnaire**

1. List two or three things you like most about the OWS program?

2. What could OWS do to improve the value of its program for your needs and student needs (e.g., kind of workshop, extent of collaboration with teacher, length and fit with school rotary schedule, etc.)?

3. Has OWS influenced your teaching practice? If so, how?

4. Has OWS had an energizing or confidence building effect? If so, how?

5. Describe any impact you have seen on your students from participating in OWS.

6. Which OWS workshop has been most helpful and why? Which OWS workshop has been least helpful and why?

7. Do you have any other comments regarding the OWS program?

Thank you for completing our survey
Appendix C. Workshop observations protocol

**STEM Study - Observation Checklist**

<table>
<thead>
<tr>
<th>Date:</th>
<th>School:</th>
<th>Grade:</th>
<th>Workshop:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>STUDENT ACTIVITIES</th>
<th>YES</th>
<th>NO</th>
<th>TEACHER ACTIVITIES</th>
<th>YES</th>
<th>NO</th>
<th>SCIENTIST ACTIVITIES</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group work/Teamwork</td>
<td></td>
<td></td>
<td>Facilitating</td>
<td></td>
<td></td>
<td>Facilitating</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Individual Work</td>
<td></td>
<td></td>
<td>Instructing</td>
<td></td>
<td></td>
<td>Instructing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communicating/Discourse</td>
<td></td>
<td></td>
<td>Modelling</td>
<td></td>
<td></td>
<td>Modelling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engagement</td>
<td></td>
<td></td>
<td>Integrating STEM Content</td>
<td></td>
<td></td>
<td>Integrating STEM Content</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Problem Solving/Decision-Making</td>
<td></td>
<td></td>
<td>Assessing</td>
<td></td>
<td></td>
<td>Assessing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Questioning</td>
<td></td>
<td></td>
<td>Inquiry</td>
<td></td>
<td></td>
<td>Inquiry</td>
<td></td>
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</tr>
<tr>
<td>Experiential Learning</td>
<td></td>
<td></td>
<td>21st Century Learning</td>
<td></td>
<td></td>
<td>21st Century Learning</td>
<td></td>
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</tr>
<tr>
<td>Hands-on Learning/Inquiry</td>
<td></td>
<td></td>
<td>Technology Integration</td>
<td></td>
<td></td>
<td>Technology Integration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21st Century Learning</td>
<td></td>
<td></td>
<td>STEM Career Awareness</td>
<td></td>
<td></td>
<td>STEM Career Awareness</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Observation Notes:

Students:

Teachers:

Workshop Leaders:

Overall Impression of Workshop (in terms of STEM):

Successes:

Challenges:

Recommendations:

Notes:
Appendix D. The behaviours being observed in the student activities during the OWS workshops

Table 10. *The behaviours being observed in the student activities during the OWS workshops*

<table>
<thead>
<tr>
<th>Behaviour</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working with a group or team</td>
<td>Students collaborating to complete the activities</td>
</tr>
<tr>
<td>Working individually</td>
<td>Students working independently to complete a task</td>
</tr>
<tr>
<td>Communicating and taking part in discourse</td>
<td>Students sharing their ideas and knowledge amongst each other and with the educators</td>
</tr>
<tr>
<td>Being engaged</td>
<td>Students being genuinely interested and involved with the content and activities</td>
</tr>
<tr>
<td>Problem solving and decision-making</td>
<td>Students working in a logical process to explore various options in order to overcome challenges</td>
</tr>
<tr>
<td>Asking questions</td>
<td>Students exploring the topics and demonstrating curiosity through meaningful questions</td>
</tr>
<tr>
<td>Learning experientially</td>
<td>Students participating in experiences that more accurately reflect the work of STEM professionals and subsequently reflecting on these experiences (Association for Experiential Education, n.d.); these experiences could include the mimicking of laboratory work, product design and testing, etc.</td>
</tr>
<tr>
<td>Doing hands-on learning and inquiry</td>
<td>Students conducting authentic inquiry to build their own knowledge; this contrasts with the aforementioned experiential learning in that it focuses on the development of questions for exploration and the subsequent discovery associated with trying to answer these questions</td>
</tr>
</tbody>
</table>
Practicing 21st Century Learning skills

Students demonstrating an ability to exhibit creativity, media and technology literacy as well as career skills during the workshop (DeCoito, 2014; Partnership for 21st Century Learning, n.d.); these include the ability to come up with new ideas and ways of thinking and proficiency with technological tools and media communication platforms; career skills can be defined as adapting to different situations and controlling one’s own behavior in order to overcome challenges in the workplace; examples of career skills included the observation of a student efficiently transitioning from one task to the next and persisting in a difficult task.
Appendix E. Teacher reflections

Teacher Reflections

Grade: School: Male/Female:

Please complete the following reflection questions on STEM education and Outreach Workshops in STEM (OWS).

Over the years, how often have you included OWS in your science program?
   [ ] once   [ ] 2 to 5 times   [ ] 5 to 10 times   [ ] more than 10 times

1. What do you like most about the OWS program?

2. Why do you include OWS as part of your science and technology program?

3. Has OWS influenced the way you teach science? If so, how?

4. Have OWS presentations:
   a. affected your motivation and confidence in teaching science over the years? If so, how?
   b. influenced you in terms of demonstrating pedagogical strategies for teaching science and technology? If so, how?

5. Have the workshops improved your content knowledge of science, technology, engineering and mathematics? How?

6. Describe the benefits that your students have realized from OWS.

7. How can OWS improve their programs to make them more relevant to student learning in science, technology, engineering, and mathematics?

8. Any other comments regarding the OWS program?

Thank you
Appendix F. OWS workshop surveys

Outreach Workshops in STEM (OWS) workshop survey

How many times have OWS conducted workshops in your classroom?

[ ] one time    [ ] two times    [ ] 3-5 times    [ ] more than 5 times

Please place a check mark in a box YOU feel best matches the statements on the left.

<table>
<thead>
<tr>
<th>Statements</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Undecided</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  The OWS program has provided me with new ideas to use in my science program.</td>
<td></td>
<td></td>
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<tr>
<td>2  The OWS has contributed to my understanding of STEM concepts.</td>
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<tr>
<td>3  I have been successful in leveraging the ideas or mentorship from OWS to enhance my science lessons and/or science teaching.</td>
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<tr>
<td>4  The OWS program provides hands-on, inquiry based investigations beyond what I am able to provide in my classroom.</td>
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<tr>
<td>5  The OWS program has increased my confidence in teaching STEM.</td>
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<tr>
<td>6  I consider the OWS program to be a good professional development opportunity.</td>
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<tr>
<td>7  The OWS workshop presenters work in a manner that values collaboration between teachers and scientists.</td>
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<tr>
<td>8  The OWS program has enriched my students’ learning in STEM.</td>
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<tr>
<td>9  The OWS program has sparked my students’ excitement and interest for STEM.</td>
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</tr>
<tr>
<td>10 The OWS program has influenced me in terms of demonstrating pedagogical strategies for teaching STEM.</td>
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</tbody>
</table>
Appendix G. Teacher information letter and consent

FALL 2014

Dear Teacher,

As you may know, Outreach Workshops in STEM (OWS) is a non-profit organization consisting of over 250 scientists and technical experts who share their excitement and enthusiasm with elementary students and their teachers. Annually, the OWS program reaches 600,000 student scientists, across 22,000 classrooms with half-day engaging workshops. Over 50,000 parent volunteers and 22,000 teachers contribute to a richer experience, working together with OWS presenters during the classroom visit. Beyond the classroom, OWS piques the interest and enthusiasm of thousands more youth and adults through participation in countless community events. The primary goals of OWS include presenting science and technology concepts in a hands-on manner to enhance students’ attitudes toward science and to foster an appreciation and awareness of science and technology amongst all children, regardless of gender, ability, socioeconomic status, and cultural background.

In keeping with their mission to engage all children, OWS is seeking to increase student interest and attitude in science, technology, engineering, and mathematics education (STEM) through complimentary classroom workshops in each of the grade 6, 7 and 8 classrooms in your school, over a 3-year period. On behalf of OWS, I am conducting Phase II of the STEM study on the impact of the program on a) student and teacher attitude and interest in STEM, b) student success/learning pathways, and c) teacher and students’ 21st century skills.

Your school participated in Phase I of the study which included grade 6, 7, and 8 classrooms. For Phase II, I am interested in collecting data in the grade 7 and 8 science classrooms in your school. The research would involve the following:

- Completion of a T-STEM survey for teachers
- Completion of a S-STEM survey for students
- Surveys will be administered during classroom instructional time by the research team. Each survey will take approximately 25 minutes to complete.
- Teacher and student interviews (approximately 10-15 minutes)
Throughout the research, I will do my best not to interfere in your everyday classroom environment and will ensure your privacy and confidentiality as well as that of your students throughout the duration of data collection and thereafter. To maintain your privacy and confidentiality, all information gathered in surveys will remain private and confidential. Your name will not appear on any data collected as codes will be assigned to you, your students, and your school. The researcher will not be communicating any evaluative comments to your principal, the parents of your students, or any person of authority. All survey data will be kept in locked files in the researcher’s office, only accessible by me. All data pertaining to this research study will be destroyed after seven years, according to Western University’s Data Security Guidelines. If you agree to participate in this study, I will seek permission from your school’s principal, from your students, and from their parents before any data collection begins.

If you are willing to participate, please refer to the attached consent form. Should you agree to participate in this study, I acknowledge that you have the right to withdraw your involvement in the study at any time, without reason and without suffering any adverse effects. All participants will be provided with a summary of the research findings once this study is completed.

Should you have further questions regarding any aspect of this study, please do not hesitate to contact me at (416) 897-7692 or by email at idecoito@uwo.ca.

I do hope that you will consider this project to be a worthwhile endeavor for your science classes and that you will agree to participate. Thank you in advance for your consideration regarding this matter.

Sincerely,

Isha DeCoito, PhD
CONSENT

I ____________________________ have read and understood
(Name of Teacher-Participant)

the terms and conditions of this study and I hereby agree to participate in the OWS
STEM Study.

_____________________ __________________________ __________________________
Date Name (please print) Signature

I can be reached at the following:

Telephone (work): _____________________

Telephone (home):_____________________

E-mail: ______________________________