Is This Real Life? How Effective Science Teachers Connect the Classroom to the Real World

By

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Abstract

The present qualitative research study examines the question: How does a sample of primary-level educators, who have demonstrated excellence in teaching science, make connections to real world issues as a tool for fostering scientific literacy in their classroom? Data was collected through semi-structured interviews with three elementary school teachers. Interview transcripts were coded for analysis and four main findings emerged: Science educators utilize the fundamentals of science, cross-curricular methods, and hands-on lessons to introduce real world connections in the classroom; effective science educators embrace technology by utilizing students’ familiarity with technology, advocating for classroom technology use, and connecting to science expertise; a number of particular challenges impede teachers from teaching science effectively; and effective science teachers look to specific markers of success when teaching science to students. The implications of these findings for future practice and research are discussed.

Key Words: Science Education, Technology, Real World Connections
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Chapter 1: Introduction

1.0 Introduction: Research Context and Problem

As technology advances at an exponential rate, Canadians are finding their lives to be more intertwined with scientific concepts than ever before. Whether it is decisions impacting climate change, selecting food at the supermarket, or what kind of energy source to utilize, decisions related to science are everywhere. Many of these scientific concepts take center stage in the political arena. For example, climate change has been a particularly hotly debated subject in Canada and across the globe in recent years. As a result, many politicians state their unwavering beliefs about the subject without necessarily deferring to the scientific experts (Raj, 2016). It is important to note that science is both a body of knowledge about the natural world as well as a lens with which people can utilize prediction, observation, and explanation for real world experiences (Lederman, Lederman, & Antink, 2013). Thus when understanding important real world issues, science and scientists can be great sources of clarity.

The recent Harper government (2006-2015), however, received a great deal of criticism from the science community for ‘muzzling’ scientists by overhauling the policies on science communications and greatly limiting the ability of scientists to publish their results and fulfill media requests (Linnitt, 2013). This disregard for the scientific enterprise from the government could reflect a greater issue, seeing that a democratic government is typically elected by a populace that shares similar values to the elected party. In a report by the Council of Canadian Academies (2014), it is noted that only 42% of the Canadian population demonstrates a basic level of science literacy and that most Canadians do not understand major scientific concepts.
Therefore, one could conclude that our recent political disregard for important scientific concepts is reflective of a larger population that undervalues scientific knowledge.

When investigating the impact of scientific literacy on a society, it is important to discuss what is to be gained by improving Canada’s current science illiteracy issue. Scientific literacy has significant impacts on an individual and their informed choices on topics related to health and consumerism, society, and how the government approaches scientific issues such as climate change, genetically modified organisms, the impact of renewable and non-renewable energy, stem cells, genetics, and nanotechnology. Positive science literacy also has an interaction with the economy, and an improvement on the quality and quantity of future science research (Council of Canadian Academies, 2014).

Education is a major factor determining science literacy, with early interventions seen as a strategic, long-term approach towards developing a skilled scientific society (Council of Canadian Academies, 2014). Not only does positive early science education improve attitudes, enjoyment, motivation, and academic achievement for students (International Association for the Evaluation of Educational Achievement, 2011), science education is required for the top jobs in Canada (Let’s Talk Science, 2013). There are ideal pedagogies for teaching science, specifically those related to connecting science to the real world and utilizing modern technology (Fitzgerald, Dawson, & Hackling, 2009; Hackling, & Prain, 2005). However, these techniques are discussed in the literature in their most general form. This current research project intends to dive deeply into what it means to use modern technology and real world connections in the classroom.

Unfortunately, in practice, science is often mischaracterized and viewed as an impractical school subject, characterized by its use of beakers and Bunsen burners (Hodson, 2003). There is
a disconnect between teaching science and actual science and its interaction with the natural world (Phillips & Norris, 2009). This manifests through poor science teaching in the early grades. Elementary teachers who must teach science from the curriculum are often under-trained in science, with about 95% of all US elementary teachers not having a science or technology background (Banilower et al., 2012). Research has found that elementary teachers tend to have low confidence (Garbett, 2003) and negative attitudes towards teaching science, which often translates to avoiding teaching it altogether (Appleton, 1995). To make matters worse, efforts to train teachers in pre-service education to adopt new, effective techniques often fail, as new teachers tend to go back to their original beliefs and techniques they learned prior to pre-service training (Skamp, & Mueller, 2001; Tobin, Tippins, & Gallard, 1995) This phenomenon, entitled ‘the apprenticeship of observation’ was coined by Dan Lortie (1975) in ‘Schoolteacher. A sociological study’. This cycle of new teachers propagating the ineffective science teaching techniques from their own educational experiences could therefore be seen as a major issue in promoting science literacy. In turn, it is vital that further research be conducted that investigates how teachers, or elementary teachers more specifically, can be prepared and supported through teacher education and development to train the next generation of scientifically literate citizens.

1.1 Purpose of the Study

The purpose of this study is to learn how a small sample of exemplary primary science educators prepare students to develop scientific literacy through connections with real world issues and adoption of modern technology in their classrooms. The primary stage of science learners is of particular interest when approaching the problem of science literacy from a human capital perspective. To have the greatest impact on society, and a larger return on investment,
science education must focus on the youngest learners (Kautz, Heckman, Diris, Weel, & Borghans, 2004).

In addition, this research discusses and reports the findings of interviews with science savvy elementary educators in hopes of sharing their instructional practices with pre-service institutions and pre-service teachers, as well as professional development facilitators and current teachers, with the hope of cultivating a more scientifically literate society.

1.2 Research Questions

The primary research question of this MTRP is: How does a sample of primary-level educators, who have demonstrated excellence in teaching science, make connections to real world issues as a tool for fostering scientific literacy in their classroom? In addition, this MTRP will investigate these sub-questions:

- How do these teachers make connections to real world issues through the use of modern technologies?
- How do these teachers conceptualize real world issues in their teaching practice?
- What challenges do these teachers face when making connections to real world issues in their science pedagogy?
- When assessing students’ development of scientific literacy, what outcomes do these teachers observe from students? What indicators of learning do they see?

1.3 Background of the Researcher

My educational and research background makes me uniquely qualified to perform this research. Having struggled with science throughout primary and secondary school, my interest in science only started to culminate halfway through my undergraduate education. I obtained a
research assistant position at a local neuroscience research facility and spent eight years gaining hands on experience learning how science can have real world applications, with a particular focus on learning and memory across the lifespan. I came to understand the importance of a scientifically literate society and became active with various science outreach opportunities, such as Let’s Talk Science and Science Rendezvous, as well as public appearances, including talks at the Ontario Science Centre and local elementary/high schools. My passion for science grew rapidly as I spent countless hours of my free time investigating scientific topics and exposing myself to the latest research findings. It was with the goal of sharing my passion for science education with young students that I applied to my current program at the Ontario Institute for Studies in Education in the primary/junior stream and hope to integrate what I learn in this research project with my own teaching.

1.5 Overview

To inform my research questions I conducted a qualitative research study using semi-structured interviews and purposeful sampling to interview a small group of teachers about their pedagogical approach to connecting real world issues with science in the classroom. In Chapter 2 I review the literature, specifically in the areas of science literacy, science education, best practices of science. In Chapter 3 I describe the research methodology employed in my MTRP. In Chapter 4 I report my research findings and discuss their significance with regards to the existing research literature. In Chapter 5 I identify the implications of the research findings for my own identity as a teacher, and for the educational research community as a whole. I also discuss a series of questions raised by the findings of my MTRP, and consider areas of future research.
Chapter 2: Literature Review

2.0 Introduction

This literature review will focus on four major themes. First, I will review the definition of science literacy, its current state, and known benefits. Second, I discuss the state of science education and review the relevant best practices. Third, I employ a critical lens and examine why our current state of science education is so dire in Canada and around the world. Finally, I review the literature on connecting teaching to the real world through science and with technological integration.

2.1 Scientific Literacy

2.1.1 Definition

The concept of scientific literacy is poorly defined in the literature. It takes on many different distinct meanings that cause it to be a controversial concept (Laugksch, 2000). Its first usage was in the late 1950s (Hurd, 1958) in context of the dawn of the scientific age for the common student in the classroom. Hurd’s (1958) belief was that an understanding of scientific concepts holds an important place in modern culture and therefore modern curriculum from Grades 1 to 12. Since this defining article, numerous researchers have shaped the meaning of scientific literacy, from learning specific knowledge to applying particular skillsets and competencies.

Similar to Hurd (1958), the Organisation for Economic Co-operation and Development (OECD, 2006) defined scientific literacy as predominantly in the realm of the acquisition of scientific knowledge. The OECD’s definition focuses on identifying scientific questions, explaining scientific concepts, understanding the characteristic features of science, and a
willingness to engage in science-related issues. The American Association for the Advancement of Science (AAAS, 1989) also takes a more knowledge-based approach to science literacy, focusing on understanding key concepts and principles of science.

The Pan-Canadian Assessment Program (PCAP, 2013) is more civically minded in its approach, implying that a scientifically literate person should be able to apply their scientific knowledge and skills to engage in science-related issues as a reflective citizen. A scientifically literate individuals’ positions on these issues should be scientifically and technologically informed. This implies that a scientifically literate citizen should hold the capacity to evaluate the quality of the scientific information they are faced with from a civic perspective.

In a review of the literature on the definition of the term ‘scientific literacy’, Laugksch (2000) attempts to synthesize all of the literature into a robust definition. His attempts were fruitless in terms of developing an absolute definition, claiming that an absolute definition is impractical. However, he did attempt to categorize the literature into three axioms of scientific literacy, based on the dictionary definition of ‘literacy’. First, he pointed to “learned” as a means of accumulating knowledge on the subject of science (Laugksch, 2000). Second, he used “competent” as a middle ground between mastery and non-mastery of the subject, therefore, one who is scientifically literate has an intermediate ability to use their knowledge (Laugksch, 2000). Finally, Laugksch used “able to function as consumers and citizens”, involving the application of scientific knowledge into society (Laugksch, 2000). This broad and inclusive conceptualization of science literacy will be what is used for the remainder of the MTRP when discussing effective science pedagogy with the goal of increasing science literacy in the population.
2.1.2 Current state of science literacy

The Programme for International Student Assessment (PISA) run by the OECD has been compiling data about science literacy from around the world. In a comprehensive report on Canadian science literacy, the Council of Canadian Academies (CCA, 2014) reported some very positive looking data when contrasting Canada’s science literacy compared to the world. Canada has the highest proportion of scientifically literate citizens when compared to the other OECD countries. Taken alone this can be an encouraging result and indicates that Canada is a leader within science literacy. However, the picture is not as positive when looking at the numbers behind this comparison. While Canada ranks first of the countries surveyed, only 42% of the Canadian population demonstrates a basic level of scientific literacy, in this case defined as having the level of knowledge necessary to comprehend the Science section of the The New York Times (CCA. 2014). In addition, the CCA (2014) reports that only 28% of the Canadian adult population are able to describe the definition of a molecule, a foundational scientific concept. Beyond scientific knowledge, the CCA (2014) reports that 54% of Canadians cannot describe what it means to study something scientifically, another major tenet of the aforementioned definition of science literacy.

2.1.3 Known benefits

There are many benefits to a scientifically literate populace as discussed in the literature. The Council of Canadian Academies (2015) describes the benefits in four separate categories: Impacts on Individuals, Impacts on Public Policy and Democratic Engagement, Impacts on the Economy, and Impacts on Scientific Research.
CONNECTING THE SCIENCE CLASSROOM TO THE REAL WORLD

The main impact on the individual is that an increase in science literacy enables the individual to appropriately parse the information they hear between fact and opinion. This extends into many of the larger issues that impact society (i.e., acid rain, GMOs, nanotechnology, vaccines) where an informed individual will be able to make better civic and personal choices (Sadler, & Zeidler, 2009). In addition, a scientifically literate individual will be better equipped to make decisions related to personal issues such as purchasing goods and services, and health care (Reyna, Nelson, Han, & Dieckmann, 2009).

The rise of science literacy in a society will push society towards more informed public policy choices, raising awareness of the important science-related issues of our time, such as GMOs, energy sources, climate change, and health research (CCA, 2014). The choices should improve policy outcomes in the society given more informed decision-making (Toumey et al., 2010).

The impact on the economy is a tenuous one, but is expected to bolster a nation’s economy by innovation and increased supply of science based skills. One example of this is the difference in job creation between technology jobs and manufacturing jobs; jobs related to technology typically lead to five additional local jobs in the community whereas manufacturing jobs typically lead to 1.6 local jobs (Moretti, 2012). This is just a small glimpse into the economy, which is a very complex system involving many aspects beyond science literacy, and it is therefore difficult to draw direct connections.

Scientific research relies on public support for funding and public interest for research participation. Typically there is very little money to be made from participating in research studies so the motivation to participate needs to be partly intrinsic. A society that values science
would be more likely support research for the sake of the research itself. Greater engagement with science will also amplify the visibility of research and make participation more accessible.

Given the state of science literacy and the clear positive benefits, steps should be taken to boost science literacy in our society and around the world. The early education years appear to be critical in giving the greatest societal gains for science literacy. Investing in human capital with effective early age science education has the greatest output of science literacy when those young students move through the education pipeline and ultimate become productive, scientifically literate citizens (Kautz et al., 2014).

2.2 Current Status of Science Education

2.2.1 What it looks like

The scientific method and scientific concepts are not inborn or instinctive traits. A child’s natural understanding of the world is often flawed and misconceived (Driver, 1989). For example, children naturally think of the earth as a flat disk (Vosniadou, & Brewer, 1992), believe that heavier objects fall faster than lighter objects (Champagne, Klopfer, & Anderson, 1980), and believe that plants are inanimate objects (Hatano, & Inagaki, 1997). The importance of appropriate scientific pedagogy is necessary to curb this natural misinformation and to foster a more scientifically literate population.

Unfortunately, the current state of elementary science education in Canada is ineffective and is leaving students disinterested or unwilling to pursue education and career trajectories in the science and technology fields (Let’s Talk Science, 2013). One major harm seen in a report on Ontario high school graduates is that those who choose to take post-secondary science degrees often do not realize the degree requirements and must return to high school to get the appropriate
prerequisites. This comes at considerable cost to the taxpayer of around $12,557 per year for each of the roughly 20,000 students who require an extra year of high school (Let’s Talk Science, 2013).

Many primary teachers avoid teaching science because they fear the content from their own education and have not received adequate training on it. They tend to simply avoid teaching it through the primary and junior grades (Abell & Roth, 1992; Appleton, 2003; Harlen, 1997). This paints a picture for students that science is simply what is stereotypically presented in the media and not applicable to the real world (Hodson, 2003); as discussed above however, science literacy has substantial implications for society.

2.2.2 Best practices

A topic that surfaces frequently when discussing the best practices of teaching science is Pedagogical Content Knowledge (PCK). It is defined as connecting knowledge of subject matter with knowledge of how to teach it. Put another way, one’s teaching should be dependent on the subject matter; for example, teaching visual arts class should differ from teaching a science class in the way the teacher approaches the material and how it is connected to other teaching methods (Shulman, 1986; 1987). The use of PCK is unique to the teaching profession and is indispensable for teaching science appropriately.

As briefly touched upon earlier with the notion of investing in human capital (Kautz et al., 2014), reaching students at an early age in science education is extremely important. The foundations of a positive attitude towards science are laid prior to a middle school age (Gibson & Chase, 2002). In addition, early science education leads to more positive attitudes, enjoyment, motivation and academic achievement in science for students as they get older (International
Association for the Evaluation of Educational Achievement or IEA, 2011). There is more willingness to pursue science in secondary school and beyond with early science education (IEA, 2011).

The context in the school can have significant impacts on the science literacy of the students. Context could apply to collegial support, the priority of science in the school in relation to other subjects, access to resources, the time allotted for science teaching, as well as the appropriate space to conduct the lessons in a meaningful manner (Appleton, 1999; Fitzgerald, & Schneider, 2013). In addition, research shows that professional development courses on science teaching can have significantly positive impacts on a teacher. A case study on a five-day professional development (PD) course for kindergarten teachers teaching science showed a reduction in dealing with anxieties, a removal of doubts regarding resource-availability, and an increased desire to learn how to engage students in the subject of science (Furtado, 2010). Van Driel and colleagues (2001) criticize the current state of PD programs, finding that only long-term PD programs can enact lasting changes in teachers’ ability to teach science and that much of the shorter PD programs’ effects are fleeting.

In terms of specific pedagogical techniques for teaching science, the research shows that actively engaging with inquiry, ideas, and evidence (Hackling & Prain, 2005) as well as introducing a variety of activities for the classroom will benefit the student’s comprehension of the material (Fitzgerald, Dawson, & Hackling, 2009). There is still substantial importance in developing and extending meaningful conceptual understandings, with explicit teaching of science skills and concepts (Fitzgerald, 2009; Hackling, 2005). In addition, Hackling & Prain (2005) identify the embracing of the modern information and communication technologies as
critical to enriching the learning of science for students (see below). Finally, it has been shown that teachers who embrace their lack of knowledge or poor science training and focus on filling the gaps in their own knowledge along with the class tend to have positive outcomes in their students’ science literacy (Appleton, 1995).

2.3 How Did We Get Here?

The current state of science literacy in Canada and around the world is clearly not in an ideal situation. There are many reasons why this is the case, many of which are beyond the scope of this research project. For instance, Seymour (2000) wrote a book as an exposé on the dropout rate of undergraduate science majors, showing that roughly 50% of all science majors quit their program prior to completion. This disinterest in science is discussed as partially stemming from a science curriculum that no longer meets the needs, interests, and aspirations of young citizens (Hodson, 2003). Thus, the focus of this research project will be on how the teaching of science is impacted by the science educators choices of real world connections and technology integration.

The training of teachers is one of the first places to look when trying to uncover why teaching practices might be ineffective. Pre-service teachers’ perceptions of their confidence in teaching science, specifically, are very poor (Appleton, 1995). In addition, research shows that pre-service teachers tend to maintain their original beliefs on science and perpetuate the way in which they were taught science in school, despite training to the contrary (Skamp & Mueller, 2001; Tobin, Tippins, & Gallard, 1995). In particular, this impact leads to a struggle to pick up novel techniques such as inquiry-based education (Dickson & Kadbey, 2014; Gustafson & Rowell, 1995; Harlen, 1997).
The feelings of inadequacy continue for practicing teachers in the subject of science, specifically in primary (Andersson, & Gullberg, 2014) and early childhood education (Garbett, 2003). These feelings of inadequacy tend to translate into relying on word for word teaching of science; something called ‘activities that work’. Appleton (2002) defines ‘activities that work’ as hands on, interesting and motivating for the children, have a clear outcome or result, manageable in the classroom, use equipment that is readily available, and are preferably used in a context where science is integrated into themes. The issue is that these techniques do not reflect the best practices discussed above. They do not tend to map onto real science as a concept and do not engage with the scientific method. Continuing this work, Appleton (2003) later demonstrated that if teachers do not teach ‘activities that work’ they tend to just avoid science all together.

The educational background of the elementary teacher is of particular concern for teaching science effectively. Having a background in the sciences would presumably increase a teacher’s confidence and enthusiasm in teaching science. A study out of the US on teacher’s background content knowledge prior to becoming an elementary teacher finds that only 5% of all US elementary teachers have a science or engineering background (Banilower et al., 2012). Moreover, teachers who tend to think negatively towards teaching science tend to shy away from learning the science content they need(Appleton, 1995) and professional development in science can be hard to enact (van Driel et al., 2001).
2.4 Real World Connection

2.4.1 Connecting the general curriculum to technology use and real world experiences of the student

Every student has his/her own set of experiences, connections, and perspectives in the world outside of the classroom, so it seems faulty to teach from a top-down, curriculum driven perspective. Educators should recognize that each student not only has different experiences, but that those experiences are valid resources for connecting the material in the classroom to the student on a deeper level (Banks, 2007). For example, when selecting coursework for a literacy class, it is important to look at the current trends in children’s literature and, ideally, to develop a profile of each learner so as to cater to their interests as well as their needs. In addition, teachers should diversify their pedagogical techniques to integrate the range of students’ experiences, especially with new media and technologies (Banks, 2007).

A study of pre-service teachers (Stover, Sheronick Yearta, & Sease, 2014) investigated connecting technology for differentiated instruction by setting up a blog system where Fifth Grade students communicated their ideas on a commonly read text. This study demonstrated an increase of communication between student and teacher through technology to allow for more specific lesson design and differentiated instruction. One potential concern, however, is the heavy reliance on a teacher’s capability in using these devices and technology in general, without specific training on them. A few testing tools have been developed to assess a teacher’s confidence in using technology for connecting with students, but more should be done to train teachers with these novel technologies (Lumpe, & Chambers, 2001).
2.4.2 Connecting with science

When designing a science lesson to be engaging and informative, research shows that teachers have the most success when building off of content that students have experience with (Andersson & Gullberg, 2014; Hackling & Prain, 2005). One such example outlines a lesson that has students in Grades K-2 learn many scientific skills, such as prediction, observation, documentation, collaboration, and data interpretation with a host of experiments performed on earthworms (Marrero, & Gunning, 2014). This particular lesson was an engaging introduction to cause and effect, and explaining those causal relationships, but with worms, which connects to children at that age. Another successful lesson was discussed in Fitzgerald (2009) where students were taught in a concrete manner by asking them to make a pizza from scratch and to discuss what that means with their parents. Giving students the opportunity to experiment in this manner is an effective way to connect their lives to the science curriculum. Extending this research beyond the classroom, Pedretti (2004) investigated the efficacy of science installations at science centres that focus on real world issues. An example of one of these exhibitions was where patrons were placed within a three-dimensional simulation game exploring the impact of building a mine in an local town. The findings were that when these exhibitions contained more personalizing content the patrons of the science centre were much more engaged and enriched.

These three examples of effective connecting of science and the real world are not the norm. Science is naturally a fluid enterprise that changes day to day, however, the science and math curriculum tend to be static and do not keep pace (Let’s Talk Science, 2013). In Ontario, the current “revised” curriculum document is from 2007, which was nine years ago as of the
writing of this chapter. Furthermore, the previous science curriculum was 10 years old when replaced by the current one.

### 2.4.3 Connecting real world and technology

As technology flourishes, the world seems to become smaller by increasing access to information and opportunity. Educators do themselves and their students a disservice by not utilizing these technologies to teach in a more meaningful and wide-ranging manner (Friedman, 2005). In addition, every generation becomes increasingly technologically savvy, and it is to the advantage of the educator to utilize this trajectory.

Use of modern technology has shown numerous benefits for education. It is important in differentiated instruction since it is multi-modal (Sweeney, 2013) and supports individual learning styles (Banks, 2007). For the classroom environment, lessons that use technology have greater student participation in more substantive science conversations and exploratory talk (Murcia, & Sheffield, 2010). Teachers, when using technology, show greater wait time, offer more open questioning, and require more participation from students (Murcia & Sheffield, 2010). When teachers use interactive whiteboards they are also able to engage in the most recent science news items, since they can be accessed directly from the Internet and projected onto the whiteboard for the whole class to take part in (Murcia, 2008). Connecting content to the real world is much more accessible with the use of cell phones, whether the students’ or teachers’, to document the world outside the classroom (Ekanayake & Wishart, 2014). Video games are an interactive medium for content that allows students to engage directly in a world designed for this interest. Minecraft has been shown to engage students with concepts of ecology, chemistry,
and physics (Short, 2012) and Microsoft has started development of an education specific edition of Minecraft (see: http://education.minecraft.net/).

There are some concerns raised in the literature about the increasing use and dependence on technology in the classrooms. Greenlaw (2015) writes a scathing paper on the ‘twenty-first century skills movement’, which has many corporate interests as technology companies attempt to cash-in on education’s dependence on technology. Additionally, Greenlaw states that the modern classroom is focused more on the technology than the teacher, undervaluing the teacher as the ‘experienced expert’, claiming that the current mentality is to get the teacher out of the way so that the students can learn. Another concern is removing a lot of the personal touch a teacher has by interacting with their classroom, even to the degree of a ‘one-size-fits-all’ style of education (Greenlaw, 2015). Beyond the technology itself, teachers can struggle with knowledge and training on new technologies, with some examples of students knowing more about the technology than the teacher (Sweeney, 2013).

2.5 Conclusion

In this literature review I investigated research on science literacy, and the pedagogical challenges and techniques related to it. This review discussed the complex nature of science literacy as a concept and the benefits to society if it is increased. It also reviews the current state of science education and the best practices revealed through research studies, and why the current state of science literacy is poor. Finally, connecting science education to the real world is demonstrated to have important benefits to students in the pursuit of science literacy, especially with the use of technology. Knowing what is required of teachers and schools is great in theory, but there are still many barriers to the implementation of effective science teaching. Teacher
confidence, lack of perceived importance, and limited science and technology resources can all stand in the way of all the best practices.

In light of this literature review, the purpose of my research is to learn how a small sample of exemplary primary-age science educators prepare students to develop scientific literacy by engaging their students with real world issues in their classrooms. In addition, compiling information about technology use and the challenges these teachers face in teaching science will cultivate understanding of this important primary science instructional approach. Ultimately, this research aspires to inform future teacher training and policy development in the area of fostering scientific literacy.
Chapter 3: Research Methodology

3.0 Introduction

In this chapter I describe the methodology I used to address my research question. I begin by discussing the general approach, procedures, and method of data collection. I then discuss the method of participant recruitment both in terms of the criteria for eligibility and how I recruited participants; additionally I include the biographies of the teachers I interviewed. Next, I explain the procedure for data analysis and the ethical considerations for the study. Finally, I conclude this chapter with a review of the strengths and weaknesses of my particular methodological choices.

3.1 Research Procedures

To address my research questions presented in Chapter 1, I interviewed experienced primary teachers with a semi-structured interview methodology. This method is considered a type of qualitative research, which is defined by Williams (2007) as an effective means of theory building through a holistic approach occurring in a natural setting and enabling the research to develop a level of detail through a direct connection with actual experiences. Qualitative research has become a favourable method of researching social science concepts by taking a post-positivist approach (Clark, 2002). This approach allows for the inclusion of data found outside of quantitative methods, not pitting qualitative and quantitative against one another, but allowing them both to have a seat at the table. Positivism is the belief that science requires direct evidence and assumes the existence of objective reality (Clark, 2002), whereas post-positivism can allow for theories, background knowledge and values of the researcher to be included
Since this MTRP aims to investigate effective science pedagogy, it couches the interview data in pre-existing theories and data as discussed in Chapter 2.

The purpose of the structured interview is to collect anecdotes from a long form medium which will allow for the derivation of holistic understanding of each interviewee’s experiences and beliefs. In this type of research study, confirmation and extension of the literature benefits greatly with a deep dialog with experts in the field. This allows the participants to embellish their responses to ensure a direct transfer of their knowledge and beliefs (Knudsen et al., 2012) and mitigates the kinds of miscommunications that can occur in a standard quantitative survey (Masue, 2013).

### 3.2 Instruments of Data Collection

Interviewing as a methodology can follow a continuum from completely structured to completely open interviewing. In this project, I collected the data using a semi-structured interview protocol (SSIP) that sits in the middle of these two extremes (Appendix B). The SSIP is a list of questions that I asked throughout the interview period (see Appendix B). According to Edwards and Holland (2013), the key features of a SSIP involve: an interactional exchange of dialog; a thematic, topic-centred, biographical or narrative approach which has central topics, themes or issues; a fluid or flexible structure; and a perspective of the data collected being situational and contextual.

Some key benefits to a SSIP is that questions are prepared ahead of time and guarantee that all of the desired content is discussed, which is especially beneficial in situations where a researcher only has one chance to perform the interview (Cohen, 2006). In addition, the interview is not so structured that the participant would not have the opportunity to express their
views on their own terms entirely, some of which may be novel to the interviewer and not anticipated in the structure. SSIPs have been demonstrated to provide reliable and comparable qualitative data (Cohen, 2006).

The data was collected using two recording devices setup for redundancy to ensure that no technical glitches compromise the data collected from the interview. I also recorded notes throughout the interview to ensure that the entire semi-structured interview protocol is completed, regardless of the order of the natural progression of the interview.

3.3 Participants

In this section I review the criteria used to select the participants in this MTRP. I also discuss the possible means of teacher recruitment. Finally, I provide an overview of the participants recruited for this study.

3.3.1 Sampling criteria

The sampling criteria I used to recruit my participants are as follows, with a discussion of each below:

❖ 3+ years of teaching experience
❖ Leadership and excellence in teaching science
❖ Has taught within the primary age range (Kindergarten to Grade 3)
❖ Preference for teachers associated with science clubs

In order to address the main research questions, the participants I am sampling from should have 3-5+ years of teaching experience. This is to help ensure that the knowledge I will be drawing from is informed from actual practice of the teacher in a classroom. My primary focus is on their first-hand teaching experience. My participant sampling also requires a
demonstration of leadership and excellence in teaching science. This reflects the critical question of how my participants employ effective science pedagogy. As discussed in Chapter 2, my focus is on the primary student age range, where the foundations for science interest are laid; thus participants must have formal experience with this population. Finally, I gave preference to teachers who are associated with science clubs, which should demonstrate an increased interest from the teacher on promoting science with the students.

### 3.3.2 Recruitment

Depending on the goals of the study, there are several methods that could be used when seeking participants. The two overarching types of sampling are *purposeful sampling* and *theoretical sampling*. Purposeful sampling is defined as selecting information-rich cases for in-depth study; those cases tend to be ones in which the researcher can learn a great deal about the issues of central importance to the purpose of the study (Gentles, 2015). Theoretical sampling is the process of using data-gathering in the study to inform subsequent recruitment. Typically this method involves an evolution of participants selection based on ongoing data analysis (Gentles, 2015). The small sample size would require the current study to use purposeful sampling to extract a great deal of information, instead of theoretical sampling which could not evolve much with only a few participants.

Choosing sample size in purposeful sampling utilizes the notion of saturation, which is that the more information the individual participants hold, the lower the amount of participants are needed. This is described as depending on five axioms: aim of the study, sample specificity, use of established theory, quality of dialogue, and analysis strategy (Malterud, 2015). The current study targets each of these axioms in a way that enables the study to minimize sample
When searching for participants to fulfill my requirements stated in the previous section, I used a series of techniques that combine purposeful sampling with convenience sampling for the sake of various time and location constraints. Ultimately, to find effective primary-age science teachers I recruited through various communities, including vocational schools, hands-on schools, farming communities, science prep teachers, individuals who have worked on the science curriculum, and science outreach institutions (such as Let’s Talk Science and Action Potential Lab). I have chosen to send my personal information to these places so that qualified teachers could contact me under their own volition without the concern of coercion.

3.3.3 Participant biographies

In order to protect the anonymity of all the participants, each individual will be referenced using a pseudonym.

Katie

Katie teaches Grades 4 through 8 science in a STEM hub school in the Toronto District School Board, at the time of the interview she was going into her 17th year of teaching. In her school she is the STEM leader and chairs the STEM committee, a group in the school that organizes whole school activities revolving around STEM. Katie has expertise in connecting science and technology through running the robotics program at her school for many years.
Alison

Alison teaches Grade 5 in a Toronto District School Board school. She has been teaching for 15 years. Alison has a varied history studying law and focusing on athletics but has recently took to focusing on science education. Fueled by her interest in biology Alison has shifted her classroom to be more science focused in recent years.

Scott

Scott has taught from Kindergarten to adults at some point during his 9 years teaching. His current position is teaching science at an intermediate level in a Barrie-area high school, however previously Scott had taught science to several primary grades over a number of years. Scott focuses strongly on introducing and running science-based extra-curricular clubs in his schools and has a strong passion for teaching the sciences.

3.4 Data Analysis

After collecting the semi-structured interview data from my participants, I analysed the data to deriving meaning. Following the procedures discussed in Knudsen and colleagues (2012), I performed a qualitative content analysis on my interview data describing meaning, intentions, consequences, and the content connected to my specific questions in the interviews. The analysis requires coding for categories and themes to derive inductive conclusions about the theories addressed in Chapter 2 and deductive conclusions based on the novel responses of my participants. This analysis first required transcribing the interviews, then coding each transcript into themes and categories by looking at the specific words and phrases. Next, I synthesized the themes and derived meaning from the themes and categories. In addition to the data derived from the participants, I looked at the sorts of things the participants did not speak to, also known as the
“null data”. This informed me of the aspects that perhaps I assumed important when originally designing the SSIP but that the participants found not necessary to go in depth with.

Rigour is an important factor when conducting a study. In the data analysis I followed the four criteria of rigour as discussed in Houghton (2013): credibility, dependability, confirmability, and transferability. These criteria ensure that the study will be meaningful in conclusion. In addition Reid & Gough (2000) list some additional ways to increase rigour, some of which will be utilized in the analysis: describe the respondents, use direct quotes, detail the interview process, description of the data conversion, immersion and developing rapport with participants, and tying into existing theories.

3.5 Ethical Review Procedures

The major ethical issues in conducting research are: informed consent, beneficence, respect for anonymity, and respect for privacy (Fouka, 2011). In this study I carried out each of these through a variety of means. All participants will be assigned a pseudonym (as discussed in Ford & Reutter, 1990) and were notified of their right to withdraw from participation at any stage of the study. In addition, their identities remain confidential and any identifying remarks given during interviews related to schools or students is excluded. There are no known risks to participate in my study as my topic is fairly uncontroversial, but I sent the interview questions to the participant ahead of time and reassured them that they have the right to refuse answering any question at any time if they feel inclined. The participants’ well-being is of the utmost importance beyond any data collection (Oddi & Cassidy, 1990). There are also concerns around data storage (Nunan & Di Domenico, 2013), such as safe storage of sensitive information. Any raw data collected was stored on a password protected device and will be destroyed after 5 years.
Participants were asked to sign a consent letter (Appendix A) giving their consent to be interviewed and audio-recorded. This consent letter gives the participant an overview of the study as well as the ethical implications and expectations of participation.

3.6 Methodological Limitations and Strengths

Since the study only sampled three participants, there is a danger in extrapolating the scope of this research. The hope is that the few chosen are rich in the information of interest of the study but without a large sampled population it could potentially be difficult to be conclusive on results (Malterud, 2015) and the findings cannot be generalized to teachers more broadly. In addition, this study cannot widen the scope to cover different populations since the ethics approval is specific to teachers. It would be interesting to get the student and parent perspectives on effective science teaching, but that must be considered in future directions. Another major concern of this methodology is that there can be researcher bias due to the interpretive nature of the data analysis, and with that, it is possible to have poor inter-experimenter reliability if another experimenter were to conduct the same experiment (Masue et al., 2013). Finally, there is a quirk of qualitative research whereby under peer review, reviewers tend to be conservative on the worth of the manuscript and are less willing to give guidance for revising the manuscript in the future (Reid & Gough, 2000). Without effective peer review, qualitative research misses out on a very important aspect of the scientific process.

In terms of strengths, the methodology flourishes in terms of getting to the core of the issues at hand. With long-form interviews, I was able to get to the minute details of a teacher’s perspective. This validates the teacher’s voice and with the semi-structure, guarantees them the freedom to hone in on the aspects of the topic that matter most to them and gives way for
unexpected resulting discussions (Masue et al., 2013). In addition, taking a post-positivist lens in doing the research respects the biases of the researcher, instead of ignoring these potential biases, as what is seen in most positivist research (Robson, 2002). Finally, qualitative research differs from quantitative research in its sensitivity to social phenomena and context. This gives qualitative conclusions a place to be situated in the research space (Masue et al., 2013).

3.7 Conclusion

In this chapter I discussed the research methodology. I began by identifying the study as qualitative in nature and described the primary method of data collection: the semi-structured interview protocol. Interviewees are primary teachers with at least 3 years experience and demonstrated excellence in science education. I then discussed how I transformed my data and interpret my data through a meaningful method of qualitative data analysis by looking for clear themes and contrasting them with the literature. I overview my ethical choices in the study with support from the literature on why these choices were made. Finally I discussed the merits, like placing the findings in the appropriate contexts and the drawbacks, like the limited scope of this study, in a qualitative semi-structured interview design. In the next chapter I will report the findings of my research.
Chapter 4: Research Findings

4.0 Introduction

This chapter presents and discusses the findings derived from analysis of three research interviews. Ultimately this chapter seeks to illuminate the question: how does a primary-level educator who demonstrates excellence in science teaching make connections to real world issues as a means of fostering scientific literacy in the classroom? This research was conducted to help elucidate concerns raised in Chapters 1 and 2 about the state of science literacy in Canada. Ultimately, this data will contribute to a greater literature on methods of teaching science by illustrating the importance of real world connections. A real world connection is a set of experiences or perspectives that a student holds outside of the classroom context. Three teachers who identified as utilizing real world connections in their classroom were interviewed during their summer holidays.

Four main themes have been addressed throughout this results chapter:

1) Science educators introduce real world-connections in the classroom through the fundamentals of science, cross curricular methods, and hands-on lessons

2) Science educators utilize technology to connect content to the real world by integrating classroom technology, embracing the students’ familiarity with technology, and to gain access to science expertise

3) Science educators face many challenges when creating effective science lessons from their personal academic background, a lack of resources, and pressures from outside influential sources

4) Observed outcomes and indicators of success of effective science teaching from
student-made connections, connections with the community, and increased student engagement.

Each of these themes will be broken down into sub-themes to help organize the findings. For each theme, the findings will be described, the data reported on, and a further discussion of the significance of each outcome will be conducted.

4.1 Science Educators Introduce Real World Connections in the Classroom Through the Fundamentals of Science, Cross-Curricular Methods, and Hands-On Lessons

Making real world connections as a means of teaching science is an integral part of this research paper. All three participants spoke of the importance of making these connections in their daily activities as well as during science class to enrich the students’ understanding of the material. Once a teacher makes the choice to pursue these connections in the class they seek out the means to do so effectively. Each participant had discussed making these connections through three clear streams: engaging their students in the fundamentals of science to ease making real world connections, demonstrating the ubiquity of science through cross-curricular programs, and educating through direct hands-on examples.

4.1.1 Science educators use the fundamentals of science to forge real world connections

Over the course of the interviews, each participant mentioned the poor practice that it is common in the classroom to teach the content knowledge without first developing their students’ knowledge of the fundamentals of science. This has the consequence of setting up the science class as a place to absorb knowledge without thinking beyond the text-book. Alison stated that it is more relevant to students if they learn about how they can personally conduct science instead of simply learning facts such as the names of scientists. Additionally, Scott indicated that
learning the skills of science, such as the scientific method, can be applied to many life situations. Thus, when a student learns how to ask an appropriate question and find the solution to a problem in science class, they can then apply these skills to their life. Scott added that “most science people would agree that the scientific method is probably the best way to solve a problem; whether it is a relationship problem or a chemistry problem, it is still the same steps.”

This notion is echoed in the literature, where Fitzgerald and colleagues (2009) identified “explicitly teaching science skills” as a major theme in characterizing effective primary science teachers. Akin to Scott’s perspective, many of these skills, such as reading a graph, predicting an outcome, or framing a question, were said to be vital not only to success in science and school, but also when interacting with the world at large.

4.1.2 Science educators apply cross curricular methods to make real world connections in science

The idea that science is everywhere was pervasive throughout the interviews. Each of the interviewees expressed a common idea that students make more real world connections in science when the content is bolstered through cross-curricular teaching methods. Their approach is to exemplify the ubiquity of science and science concepts, both through other classes as well as in the real world. Alison discussed an example from a home economics class lesson in which her students engaged in baking. In this class, she was eager to connect the lesson to both math and measurement as well as the chemistry behind the baking. A lesson of this nature encourages students to access this knowledge at home and outside the classroom. This additional activation due to real world connections strengthens a student's knowledge on the subject. Scott shared that younger students are inherently curious; he encourages this curiosity in his teaching by pointing
out science’s contribution to day-to-day items: “How does a lightswitch work? Have you thought
about the science behind the puffer you take for your asthma? Do you realize how many years of
science are behind the technology in that iPad?” Known by her students for her constant science
connections, Katie’s students unknowingly summarized this point: “You can make anything
science” to which Katie replied “But it is all science, everything is science”.

Extending this idea, Banks et al. (2007) stated that all students come with their own
background, history, and preferences which can extend the breadth of the learning environment,
encouraging even greater connections between the content of class and the outside world.
Alison’s example of baking in the classroom could benefit greatly if a student from another
culture can find a connection to their own baking experiences that other students do not have, in
this case everyone benefits from the further connections. Additionally, Andersson & Gullberg
(2014) demonstrate how this type of connection to the ubiquity of science in all subjects and
beyond can empower children to express their own understandings in the classroom, furthering
everyone’s knowledge and connection to the content.

4.1.3 Science educators use hands-on lessons to foster real world connections

The participants shared that using hands-on activities is an effective way of engaging
students with science content. Students who engage in activities that explore the content of the
lesson will more easily consolidate the information. Katie runs an extensive robotics program at
her school. She procured funding to purchase educational robots with the intent of giving the
students hands on experience in programming, problem solving, and physics. Katie designs the
tasks for her students’ robots to perform real world tasks, such as delivering the attendance to the
office. She also enters the students into the First LEGO League
CONNECTING THE SCIENCE CLASSROOM TO THE REAL WORLD

(http://www.firstlegoleague.org/), an international competition where students design and program robots to prototype the execution of real world tasks, such as garbage disposal or assisting endangered animals. Scott places his students at the center of important science debates. One instance he shared was an engaging discussion of whether it would be worthwhile to send humans to Mars. Scott states that this type of activity situates the student within the issues to allow them to connect more closely with the material. Alison addressed the importance of embracing the egocentrism of primary aged students, where young students tend to live inside their own world bubble. This lack of abstraction enables a teacher to dive deeply into the world that surrounds a student of that age. Therefore, Alison gears her lessons towards tangible lessons for her students. A lesson about soil and bugs can be explored by each student in the playground of the school. Each of these examples connect to the literature by exploring the real world connections through direct interaction (Hackling & Prain, 2005). These direct engagements with real world examples, especially through tangible means, can greatly reinforce the content knowledge.

4.2 Science Educators Utilize Technology to Connect Content to the Real World by Integrating Classroom Technology, Embracing the Students’ Familiarity with Technology, and to Gain Access to Science Expertise

Increased use of electronics and technology in the classroom has been one of the major shifts in education. The use of cell phones by the students has become pervasive in many school environments. Additionally, classrooms have seen increased usage of interactive whiteboards, iPads, and Chromebooks. The participants of this study have discussed the importance of adopting these technologies to the benefit of the students’ knowledge growth and educational
CONNECTING THE SCIENCE CLASSROOM TO THE REAL WORLD

experience. The participants identified three key ideas within the theme of technology in the classroom. Firstly, it is important to use technology in an effective manner, since there are a large variety of technologies to choose from. Teachers should learn to embrace their students’ natural inclination towards technology. Finally, technology promotes the added benefit of connecting the classroom to real science experts in the field.

4.2.1 Classroom technological equipment assist science educators in teaching effective science

Within a short amount of time, more and more technology has become available for classroom teachers. Effective science educators have been quick to adopt these technologies for use in connecting science to the students’ real experiences. All three participants named the indispensable iPad as a foundation to any science lesson. Geer et al. (2015) cautions that iPad use could offer no significant impact on student learning without extending the use beyond substitution or augmentation in the SAMR model of technological integration. This model defines technology integration in the classroom on a scale from merely enhancing the classroom to transforming it (figure 1; Puantedura, 2012). Katie uses iPads to allow students to document the phases of the water cycle, creating presentations from their captured media. This allows for a direct connection between the content of the lesson and real data they are collecting. Additionally, Katie used the iPad’s thermal imaging camera to conduct experiments on insulation and why your house gets cold in the winter. Alison found that using iPads or Chromebooks, a student could video record their steps in the process of conducting an experiment. This protected against a student’s experiment failing and having nothing to show for it, additionally demonstrating the importance of methods over results. Scott cautioned the use of
technology as a crutch: “It is important to not just have students play science games and goof around for 20 minutes; it could be the most useful thing in the world, or a complete time sink.” Using the SAMR model, despite Scott’s concerns, Katie and Alison’s examples of using the iPad modify and redefine the lessons with technology in mind, much to the benefit of the student.

Figure 1: SAMR Model (Puentedura, 2012)

4.2.2 Students’ connection to technological equipment enriches science teaching

Many teachers are hesitant to embrace the students’ digital nativeness in the classroom. Many try to keep much of this technology out of the classrooms for fear that students will be distracted. The teachers in this study found that embracing a student’s understanding of technology is a great way to encourage learning in science. The school that Alison teaches at has a stark divide between access to laptops. She found it very difficult to bring laptops into her Grade 2 classroom because “they’re little people, and little people can’t handle holding the technology to bring it to their desks.” However, she found that Grade 2 students were capable of using the laptops, logging on, and returning them to the docking station when finished. Given
this experience from Alison, it seems that opening up this technology to primary aged students is not novel to the students as much as it is novel to the primary classroom.

As a point of contention, Crook (2011) notes that a student’s recreational experience with technology does not always comport with appropriate school usages. A student’s broad and deepened engagement with technology may not be appropriate in the context of a school culture. While counter to some of the opinions of the participants in this study, Crook (2011) argues that there is an importance in gaining a sophisticated awareness of the students’ familiarity with technology beyond simply labeling them a digital native.

4.2.3 Science educators use technology to allow access to science expertise

Another critical aspect of technology use in the classroom is the access to science expert videos including a variety of science expert channels on YouTube. Alison discussed how a quick introductory video on a science concept is an easy and effective “minds-on” tool to help the students engage with the topic of the lesson. Beyond simple pre-recorded videos, Katie discussed the ease with which teachers can use Skype, or other video conferencing software, to connect to engineers or scientists on a specific science topic. She accesses a school program called Virtual Research On Call (VROC; http://www.vroc.ca/) and sets up a school assembly to allow for a discussion with a science expert. She also recounted an experience of setting up with a partner school in Egypt and having a live Skype call with them to talk about science topics such as time zones and the shape of the earth. This type of global classroom is a very novel idea at the time of this research and requires further investigation into its potential benefits since there is not yet an established literature on this topic. However, the inclusion of consultations with experts in a field is discussed as a critical tenant in the type of scaffolding discussed by Vygotsky (Doolittle,
4.3 Science Educators Face Many Challenges When Creating Effective Science Lessons from Their Personal Academic Background, a Lack of Resources, and Pressures from Outside Influential Sources

It seems evident that being an effective science teacher is an advantage to the students, however there are clear challenges that teachers must overcome to become effective in teaching science. The challenges presented in this section point to important issues that are to be considered by anyone interested in becoming an effective science educator. The key issues are broken down into three subcategories: the teacher’s background, the availability of resources, and the impact of school administration and board policy.

4.3.1 Many teachers face challenges in teaching science due to their academic background

Many individuals come to teaching from a variety of backgrounds. Some teachers set out to become a teacher from the start, others come to teaching after a career in a different field. Each of the participants in this study became effective science educators despite very different backgrounds. Alison recounts her experience largely avoiding science throughout her educational background, as she found that her focus was elsewhere. To that end, she recognizes the fear that other teachers face when approaching science material: “Sometimes even just the terminology causes fear, like the word ‘hypothesis’ some teachers avoid its usage.” Alison has since focused on developing her science program despite this lack of background knowledge. In her early teaching years she stated that she had to “pre-screen all the [information], like making sure before a lesson that you are familiar with what a cumulus cloud is.” She did this to help overcome her fears of teaching science.
Katie experienced some extremely ineffective science teachers as a student in her elementary years. She described her Grade 7 science teacher as uninspiring and would spend the period having his students copy down notes off the chalk board. She also does not recall having much science education prior to middle-school. Despite this, Katie followed through with a science education, but she recalls that many of her fellow classmates in that Grade 7 science class were put off by this treatment of science and would not pursue science in high school and beyond.

Scott found that as a substitute teacher moving around from school to school in the primary and junior ages he was the only teacher who had science qualifications. He felt very confident in covering the science material but witnessed his co-workers struggle and avoid teaching science.

These experiences connect to much of the research on teacher background in the elementary ages in different ways. Appleton (1995) discusses the large number of teachers who have poor confidence in teaching science, this applies to Alison, who suffered from anxiety around science until she focused on improving her science background. Appleton (1995) points out that there is tremendous downstream effects for teachers who lack confidence in teaching science, and unless they actively try to overcome their lack of confidence they will likely remain ineffective at teaching science. Additionally, Skamp & Mueller (2001) point out that exposure to effective practices in a teacher’s pre-service training does not tend to impact a teacher’s confidence in teaching science. This does not bode well for breaking the cycle of ineffective science teachers. While beyond the scope of the current study, perhaps more research should be conducted on identifying the characteristics that lead a science teacher to overcome the
difficulties teachers face in learning to be effective science teachers.

4.3.2 Science teachers face challenges with a lack of resources

In previous sections, the importance of technology in creating an effective science classroom was easy to state, however in practice this is not always the case. The participants were very clear that access to appropriate resources is a major contributor to creating an effective science program. Scott, who currently works as a high school science teacher, found that there was a dramatic contrast between high school and elementary access to science resources: “you might have a handful of test tubes that are sitting in the back corner [of an elementary classroom], but you are not going to have the plethora of resources that you would have had at a high school.” As Scott supply taught at many different schools, he found that there were no chemicals, dissection kits, or appropriate tables to conduct effective science lessons.

When it comes to finances, Alison identified a large disparity between her current school and former school in the amount of money they are willing to spend on science experts. Alison stated that ‘Scientist in the Classroom’ is a program that assists teachers in teaching science effectively, however it has a cost associated with it, and while her previous school would bring the program to the school four times a year, her current school might book the program once in a school year. She found that often those finances may go towards other programs such as athletics.

Katie recognizes the importance of resources and was quick to point out that she is fortunate to work at a STEM hub school. Her school focuses a lot of resources towards STEM education and it enables her to construct a comprehensive robotics program. This level of resource focus on science is fairly rare and, as Appleton (1999) points out, typically there is an
enormous gap between the resources that a science teacher requires and what they ultimately have access to, as was seen with both Scott and Alison’s experiences trying to gain access to science resources, where it is extremely difficult in certain circumstances.

4.3.3 Science teachers are challenged by top-down board pressures

Another notable challenge to science education is the impact of outside stakeholders who dictate the content taught in schools, such as school boards, parents, and the public. Katie and Alison both acknowledge that public perception can be difficult to overcome. Katie recounts a situation where she faced anger from parents of Grade 2 students who, when trying to help their child, found the Grade 2 science homework too challenging. This relates to the state of science literacy in Canada, where only 42% of the Canadian population demonstrates a basic level of scientific literacy (Council of Canadian Academies, 2014). Alison raises concerns about how the science curriculum, as designated by the ministry of education, acts like a ‘grab bag’ of content: “There are long amounts of time between learning something in one grade and then bringing that subject back several grades later.” She finds that this disjoined design of science curriculum suffers in consolidating knowledge, unlike the stepwise curriculums of literacy and mathematics.

Scott expresses similar complaints in comparison to other subjects:

Education is a 3 horse race, you go hard with math, and once math seems like it is on the good, then you go with English. Then once English is good, you’ll go with spec ed. Then it is back to math because these are the big three that you always see getting all the attention. They are the important keystone subjects and I just don’t see science as being one of those horses.

Additionally, Scott recognizes that hiring practices tend to push science educated teachers
to the older grades. He discussed how it was not integral that Grade 3 science is taught by a science teacher, just as Grade 3 music does not require a music teacher. He sees science people teaching music and music people teaching science, but regardless, there are no instruments and no science equipment; there is a clear lack of focus from the outside forces on these subjects. Fitzgerald & Schneider (2013) discuss how important it is to ensure there is enough time in the school day to fully explore science curriculum since it is exploratory in its best form. Scott was keen to point out that most elementary teachers leave science to 50 minutes of the day once a week, often at the end of the day when the home bell acts as a hard stopping point. It was a unanimous opinion among the participants of this study that the outside forces acting on them and their colleagues tends to raise barriers which are not conducive to effective science teaching.

4.4 Observed Outcomes and Indicators of Success of Effective Science Teaching from Student-Made Connections, Connections with the Community, and Increased Student Engagement

In the primary science classroom the participants in this study observed several indicators of success in their teaching. Being mindful of these successes can help promote future successful science teaching through reflection. These indicators include: students making connections outside the classroom, more active engagement with the community, and science classrooms where the students lead the discussion and are more engaged.

4.4.1 Effective science education leads to students making science connections outside of the classroom

Students beginning to take the knowledge learned in the classroom and applying it to their day-to-day life can be an encouraging example of successful teaching. Additionally, this
type of behaviour can reinforce the information being applied. Alison’s baking example demonstrates this notion of students applying what they learn to their home life. Katie focuses in her classroom on demonstrating how even the most seemingly mundane and useless science concepts still have some importance. An example Katie shared during the interview was asking students to present about applications of the differences in fluid viscosity with temperature changes. The students were able to provide a large number of real world applications. In doing so, these students demonstrated knowledge as well as excitement in the scientific concepts they were asked to learn.

Scott contrasts this idea by stating that some topics can be difficult to broach with students due to their complexity. For example, novel findings in modern chemistry are often too granular for elementary school. In light of this, Scott finds that younger students engage and connect to information that is more in line with popular science, such as psychology or space science. Scott sees these topics as ways to attract students to science. The research provides even greater methods of connection for the students, Hodson (2003) found that one of the major ways to drive engagement in a science classroom is to include socio-political action within the science class. When students see the real world implications of their actions in the classroom they will demonstrate more engagement.

4.4.2 Effective science education leads to science connections with the community

A recurring theme for Katie was the importance of the community around the school. This may have been because the school was designated a STEM school, and it relies on neighbourhood support to raise the funds to keep the STEM programs running. Initially, Katie found some hostility from the community in terms of teaching science; some parents would write
angry notes in the agendas about the unnecessary content their child was learning in science class. Katie’s solution to this issue was to design and run a STEM family night. This event was an evening where the parents of the students were invited to the school to partake in some STEM-related activities and to observe a presentation on the curriculum that their children would encounter throughout the year. This was designed so that parents knew what to expect and were not surprised by their students’ homework. Over the years, this annual activity saw increasing percentages of the school parents participating, with the past few years having “huge turnouts.” Now the parents in the neighbourhood embrace the STEM school’s science activities.

4.4.3 Effective science education leads to student-led classrooms and engagement

Each of the effective science educators in this study discussed changes in student behaviour and engagement throughout the school year. All three found that students were more attentive and eager to raise their hands to answer or ask a question. Alison found that as the students took more control of the classroom activities and she was able to step aside and not provide as much direct instruction. She found that the students begin to direct the classes for themselves, driving their own inquiry.

Scott emphasized the importance of this early engagement of students, highlighting that as they grow in confidence in the classroom they will be more willing to take science classes and understand complex concepts in the future. With the current state of science education finding students graduating high school without the necessary science qualifications for their chosen careers (Let’s Talk Science, 2013), the hope would be that increasing students’ engagement will prevent these types of issues.

4.5 Conclusion
This study found teachers who, through their experiences teaching science, shed light on the various ways to improve science education by connections to real world issues. This chapter explored four main themes that were each divided into 3 sub-themes with findings connected to prior research. First, the participants of this study discussed the ways through which they introduce real world connections by utilizing the fundamentals of science, cross-curricular methods and hands-on lessons. The research on this subject confirms that these pedagogical technique are valuable in guaranteeing that students make appropriate real world connections. The second theme delved into the topic of technological integration in the science classroom. The research participants shared their experiences using certain modern technology such as the iPad, while also ensuring that students’ digital nativeness is embraced. The ease of introducing science expertise was also critical to the research participants, and connects nicely with Vygotsky’s theories of scaffolding. There were several challenges that were quite apparent given the interviews with the participants. For science teachers to be effective it seems that many must overcome an educational history that does not favour engagement with science. Once becoming a teacher, the participants note that resources in the elementary classroom are scarce for science, and that this among other issues can be exacerbated by influential outside sources not valuing science. Finally, the participants discussed the various indicators of successful science teaching by observing student-made connections, as well as opening up the classroom to the community. The implications of these findings will be further discussed in Chapter 5. Additionally, this research will be used to make recommendations on potential areas of future research.
Chapter 5: Implications

5.0 Introduction

This chapter discusses the implications and recommendations derived from the literature and research results taken together. First I review the major findings of my research questions as discussed in Chapter 4. I will then discuss the implications of the findings for the educational community as well as my own practice as a teacher and future researcher. I will then make my recommendations for various stakeholders including: teacher education, schools and school boards, teachers, and the general public. Lastly, I present suggestions for future directions for this research.

5.1 Overview of Key Findings and their Significance

From the interview data, this research paper explores the attitudes, thoughts, and beliefs of effective science teachers in the primary aged classroom. Their passion for spreading science effectively made them ideal participants for this study and through the interview process, many of their experiences and practices can contribute to future recommendations of a variety of stakeholders. Primarily, the participants discussed the importance of introducing real world connections of science to their students, ensuring that students understand the context through which the material is being taught. Additionally, each participant conferred the importance of technology integration into the science classroom. Finally, each participant spoke of their perceived challenges and indicators of success when teaching science to young students.

The importance of introducing real world connections into the science classroom to improve science literacy was a crucial part of the hypothesis of this paper. The research indicates
real world connections are important pedagogies (Andersson & Gullberg, 2014; Banks, 2007; Hackling & Prain, 2005) however this research has not directly confronted effective science teachers in semi-structured interviews. Beyond simply making real world connections with the news, the teachers in this study discussed pushing science into the school community, connecting the content cross-curricularly, creating extra-curricular clubs for science competitions (First LEGO league) and connecting science to the world around the students since everything in the classroom environment is primarily derived from science. According to the participants of this study, these types of connections forge a deeper and more integrated level of science literacy.

Technology is not only a product of science in action; it is an important tool for teaching science effectively, according to the teachers interviewed. If available, technology can be used to modify or redefine the typical lessons one would see in a science classroom. The participants enthusiastically provided anecdotes of students using iPads and Chromebooks with excitement as the students documented their own science projects. Additionally, the participants lauded the use of video conferencing software, such as Skype, in connecting the classroom to experts in science who live around the world.

The participants were quick to identify the challenges faced when becoming a science teacher as well as fitting into the school climate, where funding and resources were scarce. Access to equipment was difficult and at times required the expense of the teacher. One participant even recounted the very stark difference he found when making the jump to high school science and suddenly having access to a dramatic increase in resources. Beyond these challenges, the participants identified indicators they see as defining a successful science classroom. Specifically, students begin to find their own science voice and take control of the
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direction the inquiry of the classroom travels. Typically this requires teachers to provide students with access to content which they will find interesting.

5.2 Implications

My research has implications both for the educational community as well as my own practice as a future teacher and teacher-researcher.

5.2.1 Implications within the educational community

The variety of strategies and pedagogical techniques discussed by the research participants are vital to educational institutions who have interests in primary science education. The research states that current teachers often lack the basic fundamental science background to feel comfortable teaching science both through their own education in Grades K-12 (Abell & Roth, 1992; Appleton, 2003) as well as through their pre-service training (Skamp & Mueller, 2001). This was echoed from my research participants who personally experienced similar experiences in their own science education backgrounds. The cycle of poor science education begetting poor science education is one that requires intervention to be broken. Currently, the Ontario Ministry of Education (OME) is pushing to prevent this exact issue but in mathematics instead (OME, 2014). Many primary teachers have math anxiety from when they learned math from teachers who also had math anxiety (Jackson & Leffingwell, 1999). The educational system of Ontario and abroad should recognize a need to break the same cycle, but for science.

Understanding the effective techniques presented in this paper could provide teacher education programs with a set of tools to equip future teachers in the hopes that they in-turn promote science literacy in the future educators found currently still in school. All three participants highlighted the importance of invigorating their students in the sciences to ensure more students
engage with science as they grow up. This can be done in ways such as embracing the most exciting new robotics and technology, or engaging the students in their environment, providing linkages between the science content and the world around them.

5.2.2 Implications for myself as a teacher and researcher

As a future teacher who has a science background, I am already highly motivated to teach science at the highest quality possible. I have spent time developing lessons and trying to captivate the students with a variety of fun and exciting lessons.

After interviewing my participants, and hearing their experiences I have begun to shape my teaching strategies in a variety of novel ways. I recognize that resources will likely be an issue in any future position I take if I stay in the primary or junior grades. However, I now understand the importance of making the best of the resources given available. An effective science teacher will scrape together materials out of recycled items or garage sales. Additionally, as stated by the participants of this study, there is an importance on advocating to the school for the importance of science equipment. According to one of the participants (Alison), often athletics supplies is a central focus of much of the budget so the science teacher must be vocal in providing a case for better science equipment. One such important technique is to demonstrate the ease through which better science equipment makes science teaching. This is something that can appeal not only to the administration, but the other more science-phobic staff.

Beyond the content of this research project in particular, I have learned the value of delving into what the research shares on best practices and new teaching techniques. I intend to follow the research as I work through my career, recognizing that my belief in science does not end in the content I teach, but also in the way I conduct my own professional development.
5.3 Recommendations

These pedagogical techniques and insights provided by the effective science teachers in this study are indispensable for not only helping to break the inadequate science teaching cycle discussed earlier, but they can also fuel a greater understanding of science across a variety of interested parties. Research of this sort can be beneficial in driving change from the largest educational institutions to the individual student. Beyond simply the core facts and knowledge of science, learning the methods of giving them context and perspective will bring the subject to life. This kind of progress is important in any domain as society strives for many of the positive outcomes an educated populace provides.

Firstly, faculties of education should think to overhaul their preservice training. As discussed in Skamp & Mueller, (2001) many preservice teachers do not receive effective preparation for teaching science. This sentiment was echoed by my participants who were typically the only teachers in their school or teacher’s education cohort that were comfortable with science. Science is a subject that is naturally self-correcting and encourages one’s attempts to gain knowledge. A quote from physicist Richard Feynman exemplifies this notion: “I would rather have questions that can’t be answered than answers which can’t be questioned.” A teacher who feels uneasy with teaching science should be comforted by the notion that stating “I don’t know” is simply an invitation to further research and not an admission of defeat. Instructing future teachers to act as co-investigators instead of arbiters of knowledge will begin to quell concerns of inadequacy in teaching science.

A large component of the challenges illuminated by the research participants is with a
lack of resources in schools. As discussed earlier, resources offer an opportunity for teachers to utilize supports through hands-on activities and technologies to assist in teaching science effectively. School and school boards could provide an avenue of greater science learning through prioritizing the purchase of science resources. Certainly with limitations on funds this may be a difficult notion to sell, however, my participants discussed the necessity of teaching science as a cross-curricular method. This would increase the value of the science resources if they can also be utilized for other subjects in addition.

Teachers could benefit greatly from taking the time to learn the newest methods of effective teaching in science as well as other subjects. A teacher’s prior beliefs are notoriously difficult to jostle (Skamp & Mueller, 2001); however, with a willing attitude and effective teacher education or professional development, teachers should be able to adopt the best practices in teaching science.

Finally, as stated in Chapter 2, there are many known benefits to society with an increase in the science literacy of the general public. The Council of Canadian Academies (2015) discussed personal benefits, civic benefits, economic benefits, as well as scientific research benefits. A population who is more scientifically literate will be able to make decisions informed by their greater understanding of how the world interacts. A pertinent example in Ontario is the ongoing political discussion about power plants. Coal plants, while currently financially cheap to run, have been shown to have deleterious effects on the population that, when health costs are taken into account, creates a much clearer case for cleaner energy such as nuclear, wind, and solar (Epstein et al., 2011). As stated by the participants in this study, connecting the concepts found within the science curriculum to real world applications will begin to make these
connections between what the students see around them and how it can be interconnected with scientific thinking.

5.4 Areas of further research

Due to some of the limitations discussed in Chapter 3, it is important to recognize the scope of the current research. Interviews with three participants, while detailed, could be expanded upon greatly to further narrow the suite of ideal pedagogical techniques and methods of connecting real world issues to science. Additionally, this research relies on anecdotal accounts of each participant’s experiences teaching in a classroom. Further research could gather data through direct observations of effective science teachers’ implementation of science education in the classroom. To further expand this idea, researchers could also observe teachers who struggle to teach science so they can compare and contrast the differences in the methodologies.

The current outcome measures of the study are indicators gathered by the research participants. In future research, interviews with the colleagues, parents, and students of the effective science teachers would be illuminating and converging evidence on the value of the techniques discussed by the effective science teachers.

5.5 Concluding comments

In this chapter, I outlined the major findings found in Chapter 4 that cover my research questions: introducing real world connections in the classroom, utilizing technology in the science classroom, challenges, and indicators of success for science education. Connecting to the real world was the central focus of much of the discussion with my research participants. They indicated that ideally a science teacher will look to push the bounds of science to encompass
much of what is discussed in the classroom, regardless of the subject. Technology is extremely valuable in the science classroom; however, while one of the research participants cautioned relying on technology as a teaching crutch, the others spoke to technology’s merits in engaging the students and providing an easy medium for making the valuable real world connections. When identifying challenges, all the participants noted the lack of access to resources and that teachers need to be advocates for procuring more science resources for their school. Finally, the research participants found that students who would take ownership over the class and direct the inquiry of the class were typically successful in reaching higher levels of science literacy.

For the educational community, the key implication is to make the OME, as well as educational institutions, aware of the current cycle of ineffective science teaching occurring in Ontario. This cycle can be broken if teachers are given the confidence and understanding of the basics of science which enforce the notion that not knowing is an invitation to learn and not a failure as a teacher. For myself, I intend to do my own part to instil excitement and enthusiasm about science in my future students, but beyond that I will advocate for appropriate science resources in the school so that each student has access to appropriate educational tools.

Recommendations were targeted at educational institutions, schools and school boards, teachers, and the general public. For educational institutions, once again, pushing the idea of embracing ‘not knowing’ as a science teacher has a great deal of value for the students of the science class. Schools and school boards should be encouraged to purchase resources for science. This typically needs some kind of teacher advocate, but would not need one if the school administration was already interested in science resources. Teachers will benefit greatly from adopting the teaching methods discussed within this paper. Finally, as discussed in Chapter 2,
there are many benefits to science literacy beyond accumulating knowledge for the general public, including personal benefits, civic benefits, economic benefits, as well as scientific research benefits.

Future research should entail expanding upon the current study through gathering information from other effective science teachers as well as the students, parents and colleagues who they interact with. Additionally, the methods could be shifted to include more observational style data collection which could lead to direct contrasts of teaching styles and their observed outcomes.

Overall, I hope that this study opens up the eyes of many of those who are in the educational community to not only the value, but the ease of teaching science at a highly effective level.
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Appendix A: Letter of Consent for Interviews

Date:

Dear _______________________________,

My name is Douglas McQuiggan and I am a student in the Master of Teaching program at the Ontario Institute for Studies in Education at the University of Toronto (OISE/UT). A component of this degree program involves conducting a small-scale qualitative research study. My research will focus on how primary teachers make real world connections and use technology to teach science. I am interested in interviewing primary teachers with at least 3 years experience who have demonstrated leadership and/or excellence in teaching science through an approach that focuses on connecting learning material to real world issues through technology. I think that your knowledge and experience will provide insights into this topic.

Your participation in this research would involve one 45-60 minute interview, which will be transcribed and audio-recorded. I would be grateful if you would allow me to interview you at a place and time convenient for you, outside of school time. The contents of this interview will be used for my research project, which will include a final paper, as well as informal presentations to my classmates. I may also present my research findings via conference presentations and/or through publication. You will be assigned a pseudonym to maintain your anonymity and I will not use your name or any other content that might identify you in my written work, oral presentations, or publications. This information will remain confidential. Any information that identifies your school or students will also be excluded. The interview data will be stored on my password-protected computer and the only person who will have access to the research data will be my course instructor Dr. Angela MacDonald. You are free to change your mind about your participation at any time, and to withdraw even after you have consented to participate. You may also choose to decline to answer any specific question during the interview. I will destroy the audio recording after the paper has been presented and/or published, which may take up to a maximum of five years after the data has been collected. There are no known risks to participation, and I will share a copy of the transcript with you shortly after the interview to ensure accuracy.
Please sign this consent form, if you agree to be interviewed. The second copy is for your records. I am very grateful for your participation.

Sincerely,

Doug McQuiggen

Course Instructor’s Name: Dr. Angela MacDonal
Contact Info: angela.macdonald@mail.utoronto.ca

Consent Form

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

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

Signature: ____________________________

Name: (printed) ____________________________

Date: ____________________________
Appendix B: Interview Protocol

Thank you for agreeing to participate in this research study, and for making time to be interviewed today. This research study aims to learn how a sample of effective science teachers of the primary grades use real world connections to teach science. This interview will last approximately 45-60 minutes, and I will ask you a series of questions focused on your teaching methods on the subject of science. I want to remind you that you may refrain from answering any question, and you have the right to withdraw your participation from the study at any time. As I explained in the consent letter, this interview will be audio-recorded. Do you have any questions before we begin?

**Background Information**

1) How many years have you been a teacher?
2) What grade do you currently teach? What grades have you taught?
3) In addition to your role as a teacher, do you fulfill any other roles in your school (e.g. coach, mentor, resource teacher etc.)?
   a) Do you have any science related roles outside of your class but still within your school and/or the formal education system?
   b) Do you have any science related roles outside of the formal school system?
4) Have you taken part in any science clubs or activities outside of the classroom?
5) Can you tell me more about your educational background?
   a) What did you study in your undergraduate degree (major/minor)?
   b) Did you do a science teachable in teacher’s college?
   c) What was your experience learning science? (*probe re: K-12 and then post-secondary). How did you enjoy your science education as a student?
d) What has been your experience learning how to teach science? *probe re: teachers college, professional development

Teacher Perspectives/Beliefs
1) What does science literacy mean to you?
2) You have identified yourself as someone who teaches for science literacy. Can you tell me more about why you believe this is important?
3) Is your sense that Ontarians and Canadians are generally scientifically literate? Why/why not?
4) What is your impression of how your school ranks in terms of science literacy?
5) In your view, how important is the subject of science compared to the other subjects in the primary age group?
   a) How would you describe the primary aims of science at the primary level of schooling?
   b) Do you believe the purpose of science changes as students get older and reach higher levels of schooling? Why/why not?
   c) You self-identified as someone who teaches science by making connections to real world issues. Can you tell me what this means to you? What kinds of topics come to mind as “real world issues”?
6) You also shared that you prioritize using technology to foster science literacy with primary-aged students. Can you tell me more about what you believe is the role of technology in the general classroom?
   a) And what about in the science classroom?
   b) And the primary level classroom?
7) How confident are you in teaching science in the classroom?

Teacher Practices
1) What does it mean to you to teach for scientific literacy?
   a) What does teaching for science literacy look like in your classroom/curriculum? *listen and then probe as necessary for specific examples
b) Can you relay for me an example of how you have taught science by making connections to real world issues?
   i) What curriculum strand/unit were you teaching?
   ii) What were your learning goals?
   iii) What opportunities for learning did you create?
   iv) What role, if any, did technology play in this lesson?
   v) What outcomes did you observe from students? What indicators of learning scientific literacy did you see?

2) How do you make decisions regarding which real world issues you are going to connect with the science curriculum?

3) What range of real world issues have you taught through primary level science instruction?

4) Generally speaking, how do students typically respond to learning science by making connections to real world issues?

5) What technologies do you use in the classroom?
   a) Specifically in teaching science?

6) In what ways do you connect the science curriculum to real world examples?
   a) What training did you have related to it?
   b) Do you connect real world examples in other subjects?

Supports and Challenges

1) What challenges do you face fostering science literacy at the primary level? How do you respond to these challenges?

2) What challenges do you face teaching science by making connections to real world issues?

3) What challenges, if any, do you face integrating technology as a tool for teaching primary science and for making connections to real world issues?
   a) What factors and resources support you in this work? Do you feel supported in your approach to teaching primary science from…
   b) Staff/colleagues?
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c) Parents?
d) Principal?

4) How could the educational system further support you in effectively teaching science to primary aged students?

Next Steps

1) What professional goals in this area have you reached?
   a) What are some goals that you are working toward in your professional practice teaching primary science?
   b) What advice could you give beginning teachers who are committed to effective science teaching at the primary level?

Do you have any other comments or questions?

Thank you for your participation in this research study.