On Scientific Literacy Development: Exploring Challenges of Science Teaching in Elementary School Teachers

By

Charlene Pan

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Department of Curriculum, Teaching and Learning
Ontario Institute for Studies in Education of the University of Toronto

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Abstract

Scientific literacy is a primary goal of science education. Scientific literacy contributes to the development of skills such as critical thinking, reasoning, communication skills, and understanding of the world around us. These skills are a transferrable outcome of science education. The purpose of this research is to explore the challenges of teaching science in elementary school teachers, by investigating current instructional practices and understanding teachers’ conceptualization of scientific literacy. Understanding the challenges teachers experience in teaching science can help us make improvements to student learning and development of scientific literacy. Data was collected through semi-structured interviews with two current educators from the Greater Toronto Area. An analysis of the data revealed an emphasis on the importance of hands on experience and inquiry learning in classrooms. The findings revealed that the challenges teachers often experience in science teaching are due to teacher education, and time and resources. This study informs the importance of scientific literacy development and provides insightful recommendations for the current Ontario Science and Technology Curriculum.

Key Words: scientific literacy, development, challenges, science teaching, Ontario
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Chapter 1: Introduction

1.0 Research Context and Problem

Science is everywhere. It is relatable and relevant in our everyday lives. From technological advances to improvements in health, medicine and much more, innovations grounded in science are ever increasing today. Science presents a way of thinking. Developing scientific literacy helps us to think critically, recognize evidence, make informed decisions about the world and helps contribute to our well-being. Acquiring scientific literacy is critical and pertinent as it prepares students to think and be responsible citizens in a modern world that is increasingly impacted by science and technology (Vieira & Tenreiro-Vieira, 2016). Skills developed in scientific literacy contribute to not only the economic well-being of the Western industrialized world, but fundamental for the improvement and economic development of poorer countries of the world (Jenkins, 2009). As a result, the primary goal of science and technology education is scientific and technological literacy (Ontario Ministry of Education, 2007). Therefore, there is interest in researching scientific literacy skills development of students in elementary schools.

There are numerous definitions of scientific literacy. However, most definitions encompass the idea that it includes socioscientific decision-making skills, and recognizes that scientific literacy is for all (Holbrook & Rannikmae, 2009). Fives et al. (2014) defines it as a form of critical thinking necessary for evaluating and making informed decisions in our daily lives. The Canadian Council of Academies (2014), quoting the U.S. National Research Council defines scientific literacy as:

Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. Scientific literacy implies that a
person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately (p. 73).

This definition expresses that scientific literacy is more than just the knowledge of science, but the ability to use information to think critically and problem solve across many disciplines.

The development of scientific literacy begins in school. Research has shown that children have the ability to gain problem-solving skills and learn complex reasoning at a much earlier age than previously thought (Wieman, 2012). There is no question that science is one of the essential core subjects taught and learned in elementary school. However, science achievement in Ontario is of concern. Reports of science assessment results from the Trends in International Mathematics and Science Study (TIMSS) showed that in 2011, test scores in science among over 9000 Ontario Grade 4 and 8 students were at the intermediate level, below science scores in Alberta and equivalent to Quebec (Fazio & Karrow, 2013). This assessment is measured on a four-year cycle, and there has been a decline in Ontario’s science achievement since 2003 with regard to students reaching the international standards established by TIMSS (Fazio & Karrow, 2013). Science educators and science education researchers believe that science education is valuable for all students, even those that do not go into science related careers (Feinstein, 2011). We can all benefit from science regardless if we pursue it in our careers, and use the skills learned in science to apply it to our everyday lives. The decrease in development of scientific literacy in students and achievement in the sciences is of concern. In order to increase science
achievement and scientific literacy development in students, there is a need to improve science teaching. This further entails the examination of the challenges teachers experience in science teaching, and current prevalent pedagogies used to teach a science curriculum.

1.1 Purpose of Study

The purpose of this study was to examine the challenges educators experience in teaching science, by investigating the use of current pedagogies, to improve science teaching and development of scientific literacy in students. Although the term scientific literacy encompasses a common idea in literature, scientific literacy among science educators has been an issue in regards to classroom practice and student learning (Smith et al., 2012). Many aspects of scientific literacy include proficiencies in science inquiry, content knowledge, and attitudes towards science (Fives et al., 2014), all of which are initiated and supported greatly by teacher practices in their classroom.

For this study, the perspectives of Grades 6-8 Ontario elementary science teachers were of interest. This is because in our society today, science and technology is rapidly growing and a need for a science education that encourages scientific literacy and critical thinking begins from the early years (Vieiera & Tenreiro-Vieira, 2016). It is stated that elementary school students hold some of the most naturally scientifically inquisitive minds, and are fascinated with curiosity about the natural world (Jenkins, 2011). More specifically, pedagogical practices by teachers in Grades 6-8 in Ontario will be examined, since instructional practices have a great effect on students’ learning and attitudes towards science.

Teachers hold a high degree of responsibility in educating the next generation, thus responsible for developing scientific literacy in students. The level of science knowledge developed in the adult population is greatly determined on the exposure of science found in the
formal school system (Council of Canadian Academies, 2014). Furthermore, it is important to recognize that scientific literacy is a transferrable outcome of science education (Fives et al., 2014). Scientific literacy contributes to critical thinking, critical reasoning, communication skills, and understanding of the world around us. The purpose of my study is to investigate how teachers conceptualize and translate scientific literacy into the classrooms to alleviate the challenges and issues teachers and pre-service teachers experience with teaching science.

1.2 Research Questions

The primary question guiding this study was: What are the challenges that Ontario Junior/Intermediate science teachers experience when teaching science to develop scientific literacy in classrooms? Subsidiary questions to further guide this inquiry included:

- How do the perspectives of scientific literacy from Grades 6-8 teachers influence their teaching practices in science education?
- How do current pedagogies used in science teaching help foster scientific literacy?
- What are Ontario Grades 6-8 science teachers’ self-efficacy on science teaching and attitudes in scientific literacy?
- How do Ontario science teachers in Grades 6-8 accommodate cultural factors of knowledge that students of diverse backgrounds bring to the classroom in science?
- How do Ontario science teachers in Grades 6-8 use inquiry in science teaching?

A further goal of this research study was to help teachers and pre-service teachers teach science more effectively, to improve science teaching and raise concern on the importance of scientific literacy development in youth.
1.3 Background of the Researcher

I strongly believe the development of scientific literacy is important in our society today and that science undeniably has an impact on our future. This topic is especially interesting to me, as I completed my undergraduate studies with a Bachelor of Science. Throughout my undergraduate career, I came to recognize two things: 1) that many people, including me struggled learning science, and in our achievements in science courses, and that 2) many people, including me, did not develop or recognize the importance of scientific literacy skills in science education before post-secondary education. These insights I have gained and experienced has drawn me to achieve further research in this particular topic.

Throughout my elementary education, I did not have a keen interest in the sciences nor did I develop the skills pertaining to scientific literacy. Furthermore, I had little understanding of the term “scientific literacy”. My concerns about science education were raised during my last undergraduate year of my studies. It began with my involvement with Let’s Talk Science, a national charitable organization that promotes learning and skills development in science, technology, engineering, and mathematics (STEM) as well as scientific literacy. As I delivered science-learning programs to various elementary classrooms, I learned and developed an understanding and importance of scientific literacy in classrooms. I also observed that there is a lack of scientific literacy development in many elementary schools. Many people believe that learning science is reserved for experts in the field when in fact many people have the capacity to learn and develop scientific literacy skills. This brought me to question the science education in today’s elementary schools: How are teachers affecting science education and development of scientific literacy to students in their attitudes and teachings? What challenges do science educators and teachers experience? How can we improve science education for students?
My value for science stemmed from my background in science and involvement with teaching. As a teacher candidate in the Junior/Intermediate grade level with a teachable in Science, I hope to enhance science education so that teachers and students can understand, develop scientific literacy skills and see that science is powerful in preparation for a new generation of high achieving individuals in our society today.

1.4 Overview

In response to the research questions I have raised, I conducted a qualitative research study using intentional sampling to interview two elementary school teachers about science education. This research project was organized into five chapters. In chapter two, I reviewed the literature in areas of elementary intermediate students, challenges of science teaching, and current pedagogies used in science teaching. In chapter three, I elaborated on the research design, which comprises of research methodology, information about the participants, data collection and limitations. In chapter four, I reported my research findings and discussed their contributions to science education in light of existing research literature. In chapter five, I have identified the implications of my research findings and how science teaching can be improved for teachers and students. I have also expressed a series of questions raised by my research findings and directions to areas for future research.
Chapter 2: Literature Review

2.0 Introduction

In this chapter, I examine literature in the areas of scientific literacy, specifically related to elementary and intermediate students. I look at current pedagogies used in science teaching, and the challenges of science teaching. More explicitly, I analyze how teachers conceptualize and understand scientific literacy in relation to the learning goals outlined in The Ontario Curriculum document for Science and Technology. Next, I consider the importance of developing scientific literacy in elementary/intermediate students by examining student attitudes towards science. I examine common pedagogical approaches and practices of science teaching and review the various challenges teachers face in science teaching by considering what aspects teachers focus on in their teaching. Finally, I will evaluate current proposals to alleviate the challenges of science teaching in the elementary and intermediate level for pre-service and in-service teachers.

2.1 Scientific Literacy and the Curriculum

Scientific literacy is a universal goal of the science education curriculum worldwide. Since its introduction in literature and society, there have been various definitions of scientific literacy. Holbrook & Rannikmae (2009) explains that scientific literacy comprises of two major views. First, scientific literacy refers to the content knowledge of science, and second, scientific literacy refers to the capability of acquiring reasoning skills to make rational decisions about societal issues (Holbrook & Rannikmae, 2009). In *Scientific Literacy and Curriculum Reform*, Dillon (2009) also expressed two visions of scientific literacy, stating that the first vision is about science, which includes laws, theories, processes, hypothesizing, experimenting, and the second vision views science as a role in decision making about socio-scientific issues. These two views
coincide and mean that to be scientifically literate, students need some knowledge about science, and the ability to use this knowledge to think critically to make decisions. An issue to consider is how to balance these two views of scientific literacy when teaching science, or if there is a need for a difference in balance between these two views. From these various conceptions of scientific literacy, it is also imperative to recognize that scientific literacy is important for everyone.

The competencies outlined in numerous scientific literacy definitions are similarly found in the Ontario Science and Technology curriculum goals (Ontario Ministry of Education, 2007, p.3). This further emphasizes the expectations that teachers provide a curriculum that gives students opportunities to develop skills of scientific literacy, and that science education strongly contributes in the development of responsible citizens. The goals of The Ontario Curriculum, Grades 1-8: Science and Technology states:

A scientifically and technologically literate person who can read and understand common media reports about science and technology, critically evaluate the information presented, and confidently engage in discussions and decision-making activities that involve science and technology (Ontario Ministry of Education, 2007, p.3).

The Ontario Curriculum furthermore explains that an important aspect of scientific and technological literacy is an understanding of the nature of science, and that teachers are expected to provide opportunities for students to develop inquiry, problem-solving, critical and creative thinking, and communication skills (Ontario Ministry of Education, 2007). Although the Ontario Curriculum has great implications for teachers to infuse scientific literacy in students, it does not address accommodations or cultural factors of knowledge that students of diverse backgrounds bring into the classroom in science. The 2007 Ontario Science and Technology curriculum failed
when tested against the Banks Model of approaches to multicultural education (Mujawamariya & Hamdan, 2013). While science is heavily influenced by the western culture, it is also important to consider the way science is done in other cultures, especially in a curriculum provided to students of diverse backgrounds in Ontario. Science has its diverse origins yet this diversity is not adequately reflected in Ontario, Canada, or the Western world (Mujawamariya & Hamdan, 2013). Furthermore, in an examination of Ontario’s science education, McNay (2000) argues that the curriculum needs to include consideration of the nature of different forms of inquiry, equity issues, and effects of certain pedagogical teachings. This is an implication for teachers to address these in their science teaching to help students develop a more socially critical view of the world. Teachers can provide learning experiences where scientific literacy is developed in multicultural contexts. When diversity is incorporated into science teaching, it can provide students with greater meaningful learning that is culturally relevant to them.

2.2 Teachers and Scientific Literacy

Scientific literacy understood by teachers is important and unquestionably affects the outcome of their science teaching, practice, and student achievement. Deniz (2011) stated that researchers suggest that elementary teachers’ epistemological beliefs about science influence their instructional practices. Since scientific literacy does not have one single concept or fixed definition, the use of this term can be challenging in terms of conveying its meaning into classroom practice, and some have argued against the use of this term completely (Smith et al., 2012). In research by Evans and Rennie (2009), teachers had conceptualized scientific literacy to about seven to eight aspects, which included science communication, investigation, science content, science related to life, resources and strategies, questioning and skeptical attitude and informed decisions. There are also concerns about how teachers’ ideas on scientific literacy can
be related to a diverse classroom of students and their cultures. It is suggested that teachers
should understand their students’ cultural values and practices relative to those of Western
modern science by exploring its differences and similarities (Brown-Acquaye, 2001). Therefore,
it is also important to consider how teachers’ experiences and thinking will shape their practice.
It is unsurprising that studies have shown that a positive correlation exists between science
teaching attitudes and the ability to be an effective science teacher (Munck, 2007). A teacher’s
confidence about science also plays a significant role in what teachers understand, believe, and
are willing to share about scientific literacy (Evans & Rennie, 2009). Teachers’ attitudes and
self-efficacy towards science are important considerations and factors that influence student
attitudes and achievement in their development of scientific literacy and science education.

2.3 Students and Attitudes towards Science

Inspiring students to learn science is one of the challenges school educators and teachers
experience. In a study conducted by Nadirova and Burger (2001), only a small percentage of
Canadian students pursue a career in science and technology, while the success of our global
economy depends on careers in scientific and technical fields. It has been found that a tendency
of decline in students’ positive attitudes towards science is prevalent near the end of primary
years (Pell & Jarvis, 2001), and a decline from age 11 and beyond (Holbrooke & Ranikmae,
2007). A decline in students’ positive attitudes towards science is of concern since developing
positive attitudes towards science in elementary years up to Grade 12 levels will help facilitate
the learning process during post-secondary school years and produce critical thinking individuals
(Glaude, 2008). In another study of students’ attitudes towards science and technology, attitudes
decreased as grade level increased, and a significant decline was observed especially in Grade 8
students (Akpınar et al., 2009). This indicates the need to further study elementary intermediate students in Grades 6-8 to alleviate the decline in attitudes towards science.

Attitudes in science are an important consideration to observe in students since attitudes, according to Ajzen & Fishbein (as cited in Osborne, 2003) are typically enduring, once formed. Although attitude and achievement in science are closely linked, it has little correlation. According to Weinburgh (as cited in Osborne, 2003), research in a meta-analysis showed that there is no strong correlation between attitude towards science and achievement. This means that children can have high achievement in science without having a positive attitude towards it. In a gender perspective, results in a study have shown a significant difference between female and male where female students have greater “interest in science” (Akpınar et al., 2009). While gender has been shown to have significant difference, culture and class can also show significant difference in the aspect of student achievements. Evans and Rennie (2009) argue that there are different aspects that lead to the variation in science achievement, which includes whether students are indigenous or non-indigenous, whether they come from rural or metropolitan schools, different socio-economic levels and the quality of science education offered in schools led by teachers. Within all of these studies, the concept of attitude towards science is quite ambiguous in measurement, and not well understood or articulated. The various factors that affect students’ attitudes towards science also need to be further examined in order to augment students’ interest in science.

2.4 Approaches to Science Teaching

There are many approaches and pedagogies used in science teaching, and they are important for fostering a generation of scientifically literate students. Science teaching practices usually reflects the goals and expectations of the science curriculum. The National Science
Education Standards (NSES) (as cited in Munck, 2007) emphasizes the value of cooperation and collaboration, science inquiry, experimenting, collecting, analyzing data, and discussing results. Similarly, the Ontario Curriculum for Science and Technology addresses that teachers provide hands-on learning for students to develop inquiry, problem-solving, creative thinking, and communication skills while also investigating, exploring, observing, and experimenting fundamental concepts (Ontario Ministry of Education, 2007). In the following section, I will concentrate on a few of the common or current pedagogies and approaches in science teaching such as inquiry based learning, literacy and science integration, and teaching through a humanistic approach.

2.4.1 Inquiry

Inquiry teaching is widely recognized and one of the most important elements of science education. Crawford provides a thorough summary of what inquiry teaching means:

Teaching science as inquiry involves engaging students in using critical thinking skills, that includes asking questions, designing and carrying out investigations, interpreting data as evidence, creating arguments, building models, and communicating findings, in the pursuit of deepening their understanding by using logic and evidence about the natural world (as cited in Ødegaard et al., 2014, p. 2998).

While teaching science knowledge and content is important, content can change and evolve. Students need to learn how to think about and evaluate information, hence inquiry-based learning. Inquiry-based learning has received extraordinary recognition, and is applicable to all subjects. It is briefly defined as an educational strategy in which learners take responsibility for new knowledge, often achieved by carrying out self-directed practices similar to the way
scientists do to construct knowledge (Pedaste, et al., 2015). It is also important to consider that teachers need to understand inquiry in order to successfully practice inquiry teaching. In a study (Ireland et al., 2012), three main ideas were found in elementary teacher’s conceptions of inquiry teaching which includes 1) Experience-centered, where teachers provide stimulating sensory experiences to students, 2) Problem-centered, where students were challenged with engaging problems and 3) Question – centered where teachers guided students to ask and answer their own questions (Ireland et al., 2012, p. 159). These main ideas found in the study, collectively encompasses what inquiry teaching practice should look like, however teacher practices in the classroom can vary according to their conceptions of inquiry. Each of these inquiry conceptions should work in conjunction with each other and not as a separate means to practice inquiry.

There is value in inquiry-based learning, as it provides a better grasp of concepts and processes of science understanding (Munck, 2007). Inquiry teaching has its place beyond science learning, and can be used in other subjects by means of using critical thinking skills and asking questions.

2.4.2 Literacy and Science

Interdisciplinary teaching with different subjects and topics are widely used and recognized to be effective in learning throughout education. Integrating science and literacy together can support learning in both subjects simultaneously, however the focus and goals of the instruction will be different, contingent on which subject is primary (McQuitty, 2016). The integration of science and literacy is a common teaching practice. Literacy is crucial in engaging in science inquiry and has a central role of text in science, involving reading, writing and being fluent in the communications of science (Norris & Phillips, 2003). Aspects of language arts can be used to support science instruction and in turn, science can provide meaningful reading and
discussions (Plummer & Kuhlman, 2008). Giving opportunities for students to read informational text can be valuable learning, and one of the science teaching practices is to integrate literacy and science together.

Guthrie et al. (as cited in Ødegaard et al., 2014) found positive results in a small-scale study with science and literacy integration; students had positive science concept learning, reading comprehension, and reading motivation. On the other hand, in a study with fourth grade teachers, it was found that students in the integrated science literacy group showed improvements in science understanding, vocabulary, and writing (Ødegaard et al., 2014). It is evident that cross-curricular teaching of science and literacy enhances literacy and science learning. Moreover, Norris & Phillips (as cited in Fang, 2006) specified that modern science is reliant on having a fundamental sense of literacy and that the capacity to read and write in the language of science is important to scientific literacy. Literacy is a crucial aspect of scientific literacy development and achievement in science. Nevertheless, further research is needed to support teaching practices with the integration of science.

2.4.3 Humanistic Approach

Teaching science through a humanistic approach is another teaching practice. Aikenhead (as cited in Jenkins 2011) argues that a humanistic philosophy helps students to understand science in a way that makes it relevant to their lives, and describes a humanistic approach as values of nature, culture, and human character of science. This can include many things such as the use of citizen science, eco-justice, and Science, Technology, Society and Environment (STSE) education, which is mandated in the Ontario curriculum.

There is a need to humanize science, and STSE education provides learners the opportunity to learn and understand science in a larger context outside of classrooms, bringing in
real world connections and relevancy (Pedretti & Nazir, 2011). STSE education emphasizes the impact of scientific and technological development on society, and its goal is to educate students to have a better understanding of the causes of social disadvantage and environmental degradation (Hodson, 2010). In a constructivist approach, learners use their prior knowledge, beliefs and assumptions to conduct inquiry, and construct their knowledge along the way to form new ideas or modify their existing ideas (Jagger & Yore, 2012). This approach allows students to consider the importance of their prior knowledge and cultural perspectives to make meaning in their learning.

2.5 Challenges of Science Teaching

Teaching science can be quite challenging and there are some shortcomings in providing effective science instruction and fostering scientific literacy. Holbrook & Ranikmae (2007) claim that one of the limitations of science teaching is that teachers focus greatly on content, and that the majority of teachers’ view of science education is perceived as building on logical positivist ideas, scientific information and concepts. Similarly, McNay (2000) argues that elementary schools throughout North America and the UK has experienced confines of science learning from the focus on “process” or methods of science. Another challenge observed is that teachers do not provide adequate time and opportunities for discussion and communication about science to consolidate the students’ conceptual learning (Ødegaard et al., 2014). Within these literatures, it is apparent that there is an overemphasis on teaching science content knowledge, and not enough focus on providing students the opportunities to think critically, to evaluate scientific information, or inquire, which fosters scientific literacy. Keys and Kennedy (as cited in Barreto-Espino et al., 2014) states that researchers found that the main problem inhibiting teaching
Science as inquiry is the limited support teachers have for planning, teaching and evaluation of inquiry.

Science is pertinent in our society and impacts our lives; therefore teachers should teach science to support development of skills in which they can use, hence development of scientifically literate students. In order to develop scientifically literate students, firstly teachers need to understand how students learn science and be versatile in their instructions. Turner (2011) presents some findings that researchers and teachers have learned in the past 30 years concerning learning sciences to support elementary and middle school students. Some of the suggestions that I found most important include determining and using students’ preexisting knowledge, providing various opportunities for students to learn the same concept in different ways, and honouring students’ cultural backgrounds and intrinsic strengths can help teachers learn how to successfully instruct and support student learning (Turner, 2011). These proposals are student-centred and provide students with meaningful learning opportunities. Although many literacies present different shortcomings of science teaching in relation to different aspects of science learning, only a few note that there are challenges in accommodating for diversity in science teaching. How students relate to and value science is indisputably shaped by their culture. The National Research Council (as cited in Glaude, 2008) states that the ultimate challenge of effective science instruction is teaching science in a way that is relevant to students’ lives. Recognizing and understanding these challenges can improve science teaching and learning in the classrooms for teachers and students.

2.6 Science Teaching Proposals for Improvements

Developments in science education have changed since the introduction and focus of scientific literacy. Science teaching has moved from traditional content knowledge teachings into
contemporary student-centred approaches such as inquiry in the classroom (Şimşek & Kabapınar, 2010). However, there are challenges in teaching practices that teachers experience. A number of proposals to improve science teaching and the development of scientific literacy in students have been identified. A common proposition is the need for teachers to represent important ideas and abstract concepts in a way that students can understand and relate to (Munck, 2007). Another proposal includes enhancing ‘task value’ to improve the science learning experiences for students (Osborne, 2003). Eccles and Wigfield (as cited in Osborne, 2003) explains that ‘task value’ is the level to which an individual believes that a certain task will fulfill their personal needs or ambitions, which involves the interest, importance, and utility to the individual. Holbrook and Rannikmae (2009) claim that to enhance scientific literacy, teachers need to help students develop collective interaction skills, personal development, communication and the ability to reason about socio-scientific arguments. Another suggestion for improving science teaching is that a balance is needed of teacher – directed and teacher guided teaching approaches (Jagger & Yore, 2012). In regards to improving science teaching with diverse students, culturally relevant lessons should take priority in classroom discussions, homework, and even scientific reasoning exercises (Glaude, 2008). Within these literatures of propositions to improve science teaching, different aspects of science teaching are focused such as in areas of science concept learning, task value, and the incorporation for opportunities to build different skills. However, an important aspect of science teaching is for teachers to understand that students are diverse and bring different experiences into science learning, which should be the beginning focus of science teaching before other proposals are fulfilled. Adamson, Santau & Lee (2003) state that to effectively teach science, teachers must not only be familiar with science context, but also be familiar with how students learn science. While these literatures
highlight different proposals for improvements, more specific methods and strategies need to be examined further.

2.7 Conclusion

In this literature review, I examined research associated with scientific literacy, elementary students’ attitudes towards science, challenges of science teaching and pedagogies used in science teaching. This review elucidates the extent that the challenges teachers have in science teaching greatly impacts student achievement and development of scientific literacy in students. It also raises questions about how teachers can overcome the challenges of science teaching and points to the need for further research on how improvements in current practices can be translated into classroom action. In light of this, the purpose of my research is to increase positive attitudes towards science and hence increase scientific literacy development in elementary school students.
Chapter 3: Methodology

3.0 Introduction to the Chapter

The purpose of this research was to examine and understand the challenges elementary school educators experience in teaching science, to improve learning and development of scientific literacy in students. This qualitative study aims to generate information gathered through semi-structure interviews with current elementary educators in Ontario. In this chapter I explained the research methodology, identifying the various methodological decisions that I have made, and the rationale for these choices, given the research purpose and questions. I began with a discussion of the research approach and procedure, before describing the main instrument of data compilation. I then identified the participants of the study, listing the sampling criteria, describing the sampling procedures, and providing some information on the participants. I proceeded to describe how I have analyzed the data, before recognizing relevant ethical issues that have been considered and addressed. Lastly, I have addressed some of the methodological limitations of the study, while also highlighting and acknowledging the strengths.

3.1 Research Approach and Procedures

The study was conducted using a qualitative research study approach, comprising a review of the existing literature pertinent to the research questions and purpose of the study, as well as the conduction of semi-structured, in-person interviews with two teachers. Qualitative research is a term that covers several methodologies and has no one universal definition. Burns and Groves (as cited in Jeanfreau & Jack, 2010) described qualitative research as focusing on the human experience through systematic and interactive approaches. Allwood (2012) stated that the goal of qualitative research is to identify one, or a small number of fundamental arguments for a certain phenomenon.
The use of a qualitative research approach was relevant to the study because the purpose of the research study was to investigate and pursue in-depth insights into the challenges current science teachers experience based on personal and classroom experiences. Qualitative research is used for this purpose since it allows researchers to explore meanings and interpretations of construct rarely seen in quantitative research (Jeanfreau & Jack, 2010), and explore a complex phenomenon within their natural and authentic contexts (Allwood, 2012). The systematic approach used in this qualitative research is the conduction of interviews as it incorporates results and data from the participants’ perspective on the phenomenon being explored, which is based on teaching experiences and practices by actual teachers.

Qualitative research differs from quantitative research. Quantitative research is designed to test a formulated hypothesis, often using statistical analyses (Tetnowski & Damico, 2001), whereas a qualitative research starts with the identification of a problem, with a research question usually implied in the problem statement, and along with the development of additional research questions (Jeanfreau & Jack, 2010). Qualitative research seeks to understand the characteristic matters of the target occurrence (Tetnowski & Damico, 2001). The information and data collected in a qualitative research focuses on how and why something is experienced or happening, not specifically about facts and figures (Jeanfreau & Jack, 2010). Qualitative research also requires a focus on one or a few individuals rather than a larger set of subjects and often employs a few participants and more variables, whereas quantitative research employs a few variables with predetermined independent or dependent measures (Tetnowski & Damico, 2001). Therefore, given my research purpose and research questions that I have, a qualitative research study was an appropriate approach for my study, as it provided me with a platform to inquire into the science teaching experiences of a small sample of Ontario elementary teachers. Suitably, I
will not only be observing how a sample of Ontario elementary teachers is experiencing challenges in scientific literacy development in classrooms, but how these teachers’ knowledge and conceptualization of the term “scientific literacy” influences their current teaching practices and pedagogies.

3.2 Instruments of Data Collection

Interviews are commonly used as a data collection strategy across many disciplines (DiCicco-Bloom & Crabtree, 2006). There are three fundamental types of research interviews, structured, semi-structured and unstructured (Gill, Stewart, Treasure, & Chadwick, 2008). However, according to DiCicco-Bloom & Crabtree (2006), no interview can truly be considered unstructured. Semi-structured interviews are generally the popular data source for a qualitative research study and are organized commonly as a set of prearranged open-ended questions (DiCicco-Bloom & Crabtree, 2006). Therefore, a semi-structured interview protocol was the main instrument of data collection used in this study.

The purpose of using interviews in a qualitative research is to contribute to a body of knowledge that is conceptual and theoretical (DiCicco-Bloom & Crabtree, 2006). The use of semi-structured interviews can be advantageous, because it has an adaptable approach. It allows the researcher to inquire deeper or elaborate on information that is important during the interviews (Gill et al., 2008). Semi-structured interviews are advantageous as information in areas or subjects I had not anticipated may come up during the interview and be relevant to my study. I can then alter, add or remove questions to effectively stimulate the necessary information. I therefore needed to be prepared to alter my planned protocol if it is not effective in eliciting the required information. I have conducted individual in-person interviews. I have organized my protocol (Appendix B) into 4 sections, beginning with the participant’s
background information, followed by questions about their understanding of scientific literacy, experiences and challenges in teaching science, current pedagogy practices they use in teaching science, and concluding with questions regarding supports, and next steps for improvements for pre-service teachers and current teachers.

3.3 Participants

Since it was not possible to study whole population, a study sample of participants was determined. The selection of participants in a qualitative research study should share crucial similarities connected to the research question (DiCicco-Bloom & Crabtree, 2006), and adhere to the specific sampling criteria. Below I addressed all methodological decisions related to the research participants.

3.3.1 Sampling Criteria

The following criteria was applied to teacher participants:

1. Teachers must have at least one year’s experience teaching.

2. Teachers must have previous or current experience teaching science in at least one the following levels ranging from Grades 6-8.

3. Teachers are currently working in Ontario.

Selecting participants for an in-depth interview is also referred to as purposeful sampling, in that it aims to select participants who fit specific criteria (DiCicco-Bloom & Crabtree, 2006). In order to address the main research question, the participants that I interviewed will have previous or current experience in teaching science in order to explore the challenges teachers experience.

Furthermore, to examine elementary school students’ development of scientific literacy, teachers teaching in the Junior/Intermediate division Grades 6-8 were interviewed. In order to maintain a geographical focus, teachers being interviewed were employed within Ontario. Lastly, I
interviewed participants varying in age and teaching specialty, in order to increase the potential richness of the data obtained from this small sample.

3.3.2 Recruitment Procedures

To recruit participants, I have contacted current teachers in Ontario and provided them with an overview of my research study and goals. Morse (as cited in Jeanfreau & Jack, 2010) identifies participants in a purposeful sample as being selected according to the needs of the study, and volunteer/convenience participants as individuals who are not known to the researcher but volunteered to participate in the research study. Due to the methodological parameters of my research study, I employed a combination of both purposeful and convenience/volunteer sampling. The sampling procedure was purposeful in that participants of this small sample met a set of defined criteria in order to provide the richest possible data. As a pre-service teacher who has lived and completed elementary education and practicums within the Greater Toronto Area, convenience sampling was employed, as participants were obtained through existing connections with current teachers within the region.

3.3.3 Participant Bios

Robin is a passionate outdoor educator that currently teaches Grade 7/8 homeroom with a specialization in Science. Robin has fourteen years of teaching experience, teaching science in each of those years, and having spent five years in outdoor education. Robin is involved in school clubs such as taking the lead as head of the Eco team at her school and has been involved with Math Olympics. Robin has a Bachelor of Science, and a Masters in Zoology.

Jane is currently a Grade 6 classroom teacher that teaches all subjects. She has six years of teaching experience, and has taught science in all years. She has a teachable in Health and
Physical Education in the Junior/Intermediate level and is also Primary/Junior qualified. Jane has a Bachelor of Science in Psychology and a Master of Teaching.

3.4 Data Analysis

The analysis for this study began with a review of the transcribed interviews conducted by carefully analyzing the responses of the participants. Each interview was audio recorded on a digital device and then transcribed into text. After transcribing the interviews, I organized the data into codes. Many qualitative research projects use this general process of data analysis whereby data in the form of transcripts are analyzed by reducing the data into themes through a process of coding and then finally representing the data in a discussion (Creswell, 2013). Subsequently, the codes I have generated were grouped into prevalent and relevant common themes and four overarching themes arose that were addressed by my participants.

The four prevailing themes evident in the data were:

1) Teacher Perspectives of Scientific Literacy
2) Teaching Practices
3) Challenges
4) Recommendations

In a qualitative research project, data analysis involves confirming preliminary interpretations, and eventually concluding a theory or final interpretation from the data (Jeanfreau & Jack, 2010). Finally, I interpreted the data, compared the data to existing literature, and discussed the significance and new insights gained from my findings.

3.5 Ethical Review Procedures

In a qualitative research, four ethical issues are related to the interview process, which includes: reducing risk of unanticipated harm, protecting the participant’s information,
effectively informing participant about the nature of the study, and reducing the risk of exploitation (DiCicco-Bloom & Crabtree, 2006, p. 319).

I followed the ethical review procedures for the Master of Teaching program. The participants of this study were given a consent form (Appendix A), which stated the exact purpose of the study, the commitment they will need to make, how their identity will be protected, and their rights as a participant to stop the interviews at any time. The form also informed the participants that their interviews will be recorded for accuracy purposes and that the data they provided would be used strictly for this study. In addition, it gave the participants the right to receive a copy of the full written report of the study upon its conclusion, if they choose so.

I do not anticipate any ethical issues as the nature of the study, meaning the type of information being gathered from participants and information gathering instruments, are not overly controversial, sensitive, or intrusive. Therefore, I do not believe it will affect the lives of the participants. Pseudonyms were used in the writing of this paper as will be in any subsequent presentations of the work. Also, all participants signed the consent form only if they wished to participate and were fully aware of what the study entailed.

3.6 Methodological Limitations and Strengths

There are many limitations of this research study. The first and largest limitation to this study was the lack of scalability. The sample size consisted of only two participants, which is not representative of the population of Canadian teachers that teach science in the elementary level. It was also problematic to take general broad views from the information gathered from the data, as this is a small-scale research study concerning science education in Canada and not representative of all science teaching globally. However, the strength of this methodology is that
using a qualitative approach provides a much deeper understanding on the topic of challenges of scientific literacy development in elementary schools, than a rigid quantitative approach would have. A qualitative approach can help transfer knowledge gained from this study into a broader context.

Moreover, the ethical parameters of the study as per the Master of Teaching Research Project guidelines allowed me to only interview teachers, and not students on the topic of scientific literacy development. This was a drawback, because how teachers conceptualize scientific literacy and translate it into the classroom directly affects students, whom are the next generation of scientifically literate citizens. Since student perspectives were excluded, therefore the effects of teacher pedagogy cannot be observed. However, interviewing teachers was also a strength, because the data gathered validates teacher voice and experience, it provided teachers a platform to address important matters about science education, and construct meaning from their own teaching experiences.

In a qualitative research, the researcher plays a fundamental role as the data collector and data interpreter. This is a drawback and important to acknowledge, as I will have inevitably contributed my own biases, experiences and shortcomings within the data. However, this may also be seen as a strength since I have a background and teachable in science in the Junior/Intermediate level. I can use my experiences as an advantage, providing some proficient understanding of scientific literacy in the classrooms as a pre-service teacher, and using that to think critically when collecting and analyzing data. Another limitation to this study was the time restraint, as this study was conducted over two years.
3.7 Conclusion

In this chapter I described the research methodology. I began with a discussion of the research approach and procedures, examining the significance of qualitative research and its relevant use in the study. I also distinguished the difference between qualitative research and quantitative research. I proceeded to discuss instruments of data collection using semi-structured in-person interviews and its adaptable approach. I then identified the participants of the study, using purposeful sampling. I also explained the recruitment procedures, using purposeful and convenient sampling. I then proceeded to describe how I have analyzed the data by reviewing individual interview transcriptions and observing for patterns and common themes across the data. Ethical review procedures were also addressed, such as consent, risks of participation, protection of participant information, rights to withdraw, and data storage. Lastly, I discussed the methodological limitations of the study, such as the lack of scalability and student perspective, while also highlighting some of the strengths of the study such as teacher voice and experience. In the next chapter, I report on the findings of the research.
Chapter 4: Findings

4.0 Introductory Overview

Elementary school science teachers experience many challenges and issues in teaching science (Hodson, 2002). In response to the concerns of the challenges that elementary teachers experience when teaching science, I interviewed educators in Ontario to further examine this phenomenon. In this chapter, I present the interpretations of my findings from the data collected from two semi-structured interviews. An analysis of the interviews revealed an emphasis on the importance of hands on experiences and inquiry learning in science classrooms. After examination of these transcripts, identification of four overarching themes emerged: 1) Teacher Perspective of Scientific Literacy, 2) Teaching Practices, 3) Challenges, and 4) Recommendations. These themes provide important insights into improving science teaching and its connection to developing scientific literacy in students.

4.1 Teacher Perspective of Scientific Literacy

Each of the participants expressed different perspectives of what scientific literacy means to them. Smith et al. (2012) affirmed that teachers’ notions of scientific literacy, how they plan their curriculum, what they value for their students’ learning and how they provide these learning experiences for their students are the issues that arise when scientific literacy is considered. It is clear from what they expressed during the interviews that their different background and experiences in science has an influence on their perspectives, and thus influences their classroom practice. These themes will be further divided into the following subthemes: Understanding, Experience, and Beliefs.
4.1.1 Understanding

Each participant’s understanding of scientific literacy was expressed when asked, “What is your understanding of scientific literacy?” Robin explained:

Scientific literacy means a couple different things. It means really understanding the concept of what science is, and that whole process of asking questions and coming up with that experiment to answer those questions, and understanding that whatever the answer is, whatever observations you make, that as a scientist you have to be able to explain your observations, instead of giving a cut and dry answer.

In contrast, Jane was unable to articulate an understanding of scientific literacy, and responded, “What’s the definition?” Upon reading to her the definition of scientific literacy defined in my Chapter 1, she expressed that scientific literacy was extremely important, and addressed the question of how to make it feasible especially for teachers who do not have a strong science background. Jane also stated that even though she had completed the mandatory science-teaching course for her teaching degree, she felt “ill prepared actually coming into the classroom.” She further stated, “…the science teaching course and I’ll be honest with you I don’t think it was very helpful. There was no clear connection to the Science Curriculum.” This illustrates that teacher experiences have an impact and contributes to their knowledge and understanding of scientific literacy.

4.1.2 Experience

Each of the participant’s different science education experiences in elementary school was revealed. Robin expressed her memory of learning science in Grades 7-8. She discussed about her school having serious labs and biology rooms with aquariums, and that she got to dissect a frog. Robin stated, “What I really remembered from that school was I really got to learn
how to use tools and equipment. It was hands on stuff, hands on stuff has always really stuck with me.” Robin also mentioned that she attended science field trips and her science teacher incorporated fun science activities outside of the Science curriculum. In contrast, Jane expressed a lack of learning science in elementary school. Jane stated, “I don’t really remember learning science as much. I think the focus in elementary was Math and Language.” She further stated, “I do not remember a single hands on assignment or project in Science.” Overall, these teachers pointed out that hands-on learning was memorable and valuable in science education.

4.1.3 Beliefs

Both teachers have different beliefs on scientific literacy and science education, in terms of what they conceptualize scientific literacy to be and what they value in science education. However, both teachers also share a commonality that development of lifelong scientific literacy is important. Robin explained the importance of scientific literacy in the following statement:

We take a look at this current society that’s developing people who don’t use evidence. Pseudo science and people who don’t believe in vaccines is absolutely terrifying. We will enter a dark age, if we don’t get this turned around. People just believe in absolutely everything they read online, this inability to question because it looks scary, I don’t know if it’s scary to question, I don’t know. In my mind, it’s one of the most important skills, it’s that really serious critical thinking. That needs to be a lifelong skill, even if that kid is not going to be a scientist. But I think science class is a great place to foster that.

Jane relates scientific literacy as having the skills to question and conduct critical thinking. Furthermore, she explained that scientific literacy comprises of lifelong skills for everyone, even if you are not going to be a scientist and that science education is a great place to develop these skills. Jane related scientific literacy as something one does not normally think about, but is
embedded in our everyday lives. Jane commented, “We just overlook it, but it’s important.” Jane also explains that she believes the goals of scientific literacy are to develop a curious and critical thinker. However, she further expresses that there is a greater active component. Jane concludes:

To me, scientific literacy is, it includes that, but to me there’s a more active component to it, like if there’s something happening in the real world, can we do something about it? Can we identify the issue, can we find the resources to help us solve that problem, if there are different ways to solve it, are we able to find the way that works the best that we think in that situation?

These perspectives relate to the important roles of scientific literacy according to the High Level Group on Science Education (as cited in Dillon, 2009):

Equipping every citizen with the skills needed to live and work in the knowledge society by giving them the opportunity to develop critical thinking and scientific reasoning that will enable them to make well informed choices. Science education helps fighting misjudgements and reinforcing our common culture based on rational thinking (p. 205).

Although both teachers have different backgrounds and experiences in science, they both expressed the importance of scientific literacy in fostering critical thinking and problem solving skills in science education.

4.2 Teaching Practices

The understanding of the participants’ teaching practices can be further divided into five subthemes: Teacher Pedagogy, Hands On, Inquiry-based learning, Assessment, and Cultural Knowledge. Although both teachers had different teaching pedagogies, hands on and inquiry learning were repeated ideas mentioned by both. Experiences and beliefs from their teaching pedagogy, and approaches to hands on and inquiry provided insightful information to how they
structure science lessons in their classrooms. Similarly, how teachers assessed for student skills and knowledge pertaining to scientific literacy was important to identify transferable outcomes of science education. Lastly, how teachers accommodated for cultural knowledge in science was alluded to identify how and if diversity was included in science teaching.

4.2.1 Teaching Pedagogy

Both teachers expressed their teaching pedagogy and how they related or incorporated that into their science instruction. When asked directly “What is your teaching pedagogy and how do you incorporate that into your science teaching?” Robin responded:

I’m a classroom teacher as well as an outdoor educator, so my big thing is outdoor learning. That is my number one goal of anything that I teach, hands on, concrete learning, directly applicable to the kids’ lives, that is how I teach.

Robin further explained how she divided her science block into experiment and consolidation. Each week, her students are provided the opportunity to do hands on learning. Robin further provided an example of how that is practiced in her classroom:

I kind of flip how I teach things, I often do an experiment first and get the results from an experiment and then use that as a concept rather than the other way around. For example in Grade 8, the systems and action unit, which is a difficult scary unit for a lot of teachers. How do you teach concepts of work, so I have an experiment first, I don’t tell them what it is, I tell them to calculate a number first, and we look at it, and look at the relationships between them. Then I have them come up with why is the number for work the same no matter how much we change the experiment, you know.

Robin uses inquiry to first provide students with the skills they need to learn and understand concepts in a science topic or unit. She confirms, “…that is what my teaching pedagogy is,
here’s some skills, here’s why we need them, here’s a task to complete with those skills, now go! I do that with everything, with math and language.”

Correspondingly, Jane explained that her teaching pedagogy is, “Student centred, hands on, real world connections, and a collaborative approach.” Jane also highlighted that she places more importance on the scientific process rather than accomplishing all the expectations in a curriculum. She believes skills such as the ability to evaluate data, analyze, accept or reject a hypothesis or idea was important. She supported this by saying, “The scientific process, ask a question, what’s the problem, a hypothesis, that whole process I also really enforce that or put that in the forefront of my teaching as well.” The participants’ responses coincided with the values that the National Science Education Standards (NSES) (as cited in Munck, 2007) places on cooperation and collaboration, science inquiry, experimenting, collecting, analyzing data, and discussing results in science pedagogy. Therefore, teacher pedagogy and practice in classrooms is critical to success and achievement in science education.

4.2.2 Hands On

Robin indicated that she is an outdoor educator, and she incorporates place-based learning into her teaching practices in science. Place-based learning was established with the notion that learning occurs most naturally when learning in local environments, with an authentic purpose (Buxton, 2010). Place-based learning is powerful in that it allows for real world problem solving opportunities, and serves to strengthen children’s connections to others and the local community they live in (Smith, 2002). She stated, “We do place-based learning as well as we have a pond and park behind the school and that’s where we’re learning, we’re not learning in the classroom. They’re doing all their measurements outside in the pond.” She provides hands on activities for her students by incorporating place-based learning. Likewise, Jane also talked about
her use of hands on approach, and making it practical for student learning. She stated, “I like them to kind of get their hands wet and try things, like I said experiment, art, creating…” and “…hands on, I like to do a lot of demonstrations and experiments, and I like to make connections to the real world and how that specific concept applies to every day life.” In conclusion, both teachers expressed that hands on learning is crucial for providing practical and meaningful experiences for students in science education.

4.2.3 Inquiry-based Learning

Both teachers mentioned the use of inquiry in science teaching and also in other subjects of instruction. It is apparent that inquiry-based learning has become a common teaching practice in education. Teaching approaches have shifted from lecture-based methods to student-centred approaches towards inquiry (Şimşek & Kabapınar, 2010). More specifically, science inquiry “encourages development of problem solving, communication, and thinking skills” (Cuevas, Lee, Hart, & Deaktor, 2005, p.338) as students ask questions and find solutions. These skills are regarded to be essential in the 21st century world (Cuevas et al., 2005). Robin has a strong belief on using inquiry, and asserted, “…inquiry based learning is very powerful.” She supported her perspective of inquiry-based learning by explaining an example she did with her students:

In my mind it works the best when you know where you want the ending product to go, or the end result to be. For example the balloon pop. So this is their task, what is the criteria going to be, so they came up with the criteria with me, and then after that as long as it hits the criteria and you accomplish the task of popping the balloon, how you get there is up to you. So giving that framework is really important. If you don’t give enough of a framework, inquiry goes… it’s messy.
Robin emphasized the importance of guiding her students through the inquiry process and co-creating the evaluation criteria with her students. She also strongly believes that inquiry should be embedded in other subjects. She supported this argument by saying, “…it’s kinda funny because they talk about science for the inquiry-based learning, but we should be doing inquiry learning for other subjects too. I’ve been practicing and experimenting inquiry with other areas too, it seems scary, it’s been lots of fun.” On the other hand, Jane practiced inquiry in her classroom, but emphasized the importance of making inquiry meaningful. She stressed, “…we’re asking a lot of questions, but we’re not doing these questions justice if that’s how you decide to answer it. So I felt like we were not positively reinforcing their questioning skills, so that was my first challenge.” Jane views developing questioning skills as challenging and important for fostering effective and meaningful inquiry.

4.2.4 Assessment

The consideration of how teachers assessed their students was valuable in order to measure learning outcomes and gains from teaching practices. More specifically, teachers were asked how they assessed that students have gained skills pertaining to scientific literacy such as critical thinking and/or problem solving skills. Robin responded by stating and providing an example:

I go through a series of experiments so they understand solutions and mixtures. We do a whole bunch of little labs so they have an idea of question, hypothesis…etc, they get all that down, and then I give them a task they have to do. For example, a mixture of salt, pepper, sand, oil, water, and pins and their task is to separate and what order, but that’s the assessment of if they understand solutions, mixtures and all those sorts of things. B), They should know the techniques to do that, so there’s assessment there. And C), they
have to write a lab report about it, so I can go back and look at all of that, so that comes with the design.

Robin provides assessment to her students in various ways. She assesses students for concept understanding and content knowledge through experiments, and scientific process gains through the techniques the students use in labs. Robin uses lab report writing as assessment and firmly believes that communication, and using scientific language is an important skill that students need to develop. She states, “I tend to be very heavy on the writing part.” Robin also believes that assessment should be done intentionally. Intentionally meaning that assessments are carefully planned out to measure specific expectations and learning goals. Jane shared her response on how she assessed her students by stating:

…I feel like that’s how I can see, like they can turn to the resource that they think would be appropriate, and if it doesn’t work that they can try something else. I think a lot of it is perseverance, if this works great, and if it doesn’t, let’s try something else, and always reflecting that process. If they are reflective in nature then they would know if they are going down the right path or not they should be able to figure that out. If they are always having to come to me, which is fine, like I can facilitate their learning, but if they’re coming to me like, “What do I do next? What do I do next?” To me, they are not engaging in scientific literacy, because they’re still coming to me, right, for me to direct them rather than for them to ask that question.

This contributed to her belief that when students use metacognition, reflect on their learning process and are self-directed means that they are engaging in scientific literacy skills. The measure of scientific literacy expressed by both teachers encompasses how scientific literacy and science education aims to be measured relative to current literature. Fives et al. (2014) explained
that measuring scientific literacy and science education gains is greater than the demonstration of knowledge, it includes students’ beliefs and motivation. Fives et al. (2014) further emphasized that one must also be able to engage in knowledge, to use information for decision making when presented in daily life. Both participants illustrated that assessment is a valuable tool and that using various methods of assessment was crucial for measuring science education and scientific literacy outcomes.

4.2.5 Cultural Knowledge

The participants had various answers when asked how and if they include cultural factors of knowledge in science education. Indeed, science education in Canada is through a Westernized perspective. In a research, Mujawamariya & Hamdan (2013) showed that when the Ontario 1998 and 2007 Science Curriculum was tested against the Banks model for ensuring racial, ethnic, and cultural diversity, it failed to challenge the perception that science is predominantly of Western origin. Diversity exists in all classrooms and Glaude (2008) stated that culturally relevant lessons should be a priority to improve science teaching, which includes culturally relevant discussions, homework, and scientific reasoning exercises. Robin stated that she does not include a lot of diversity in her science teaching, but additionally explains how classrooms are bringing in more First Nation perspectives. She articulated this idea by stating:

…the First Nations influence, is something we’re bringing a lot into the classroom now, and it’s good and necessary, but one of the questions I have which I’m hoping to learn is, what is the difference between the First Nations worldview and science? I can see it ties into some units for example the ecosystem unit right, and the concept of interconnectedness, it’s a great place to bring First Nations teachings into the science classroom…but I don’t know how it can fit into physics.
Congruently, Jane claimed that she had never thought about including culture and diversity into science education and reasoned with, “Well, even the curriculum tells us to focus on Canadian contributions to space, or space exploration…” However, there are implications to bring cultural knowledge into science education to enhance learning for students. Chiu & Duit (2011) stated that the abundance of perspectives and traditions of science education worldwide is “a major source for further research that leads to improvement of scientific literacy worldwide.” The lack of cultural diversity in science education calls for educators to challenge the concept that science is primarily Western, and provide culturally relevant experiences for students to enrich learning.

**4.3 Challenges**

Certainly many teachers experience challenges in science teaching. Participants were asked about the challenges and limitations they encountered. To examine in greater depth, the following section will be lengthened to two subthemes associated with the participants’ responses to challenges: Teacher Education, and Time and Resources.

4.3.1 Teacher Education

In regards to self-efficacy, participants were asked about their own strengths and weaknesses in science teaching. Robin was least comfortable with physics because it involved math. She felt she sometimes did not “have enough information to adequately help kids answer questions.” Robin’s strength lies in the biological sciences, she adds, “…since I have a Masters in Zoology so anything to do with biology I’m good to go, I’m very comfortable with that.” In contrast, Jane felt teaching science was challenging, she reasoned, “…because Science is not my teachable and talking to other teachers whose teachable is Science, I can see it in them, that their science program is amazing, just the way that they talk about it. I think they take for granted what they actually know.” Jane’s strengths include that she is self-motivated to improve her
teaching; she stated, “I always want to improve my understanding, to have a better idea, to make things hands on.” Jane explained that by filling her own gaps and knowledge, she can “hopefully provide more rich experiences for them,” as she referred to her students. She further asserted that, “…as I’m becoming more knowledgeable about the curriculum expectations, like I keep pushing to learn more, every year, I can go deeper and deeper and deeper, so I can bring more enthusiasm just because I have more confidence as a teacher.” This shows a relation between teacher knowledge and student engagement. It was also stated by Henson, Kogan & Vacha-Hasse (as cited by Wang, Tsai & Wei, 2015) that a solid sense of teaching efficacy can influence effective teaching and student achievement. Additionally, Robin indicated that she would also like to improve her teaching in designing science experiments and working on various ways to assess her students. Both teachers stated that being knowledgeable in science was important but did not include how they would differentiate teaching science. Research indicated that it is important to consider that to teach science effectively, teachers must also be familiar with how their students learn science, and not just be knowledgeable in science (Adamson, Santau & Lee, 2003). It is clear from the participants’ response that having an educational background in science is beneficial.

4.3.2 Time and Resources

Both participants strongly expressed the lack of time and resources as a challenge. Robin discussed time and equipment as an issue and challenge. She supported this by saying, “There’s so many things I’d like to do, but not enough time…honouring all the parts of the curriculum is challenging.” She expressed her thoughts on the issue of resources by asserting:

You need to have equipment, for example you can’t do basketball without the balls. You can’t do a band program without the instruments. You can’t do science without the
beakers and the scales and the flasks and the microscopes and all those things and if you
don’t’ have it at your school you have to know where you can get those from. The other
thing is teachers don’t know how to use it, or where the equipment is kept.

Again, a lack of knowledge was noted by Robin as a challenge when teachers do not know how
to properly use equipment in their science instruction. Robin also claimed that she spent a great
amount of money on science equipment. Jane further elucidated the claim of lack of resources by
stating, “…we don’t have enough resources, not even in terms of teacher resources.” She
explained that even setting up science equipment, and organization was time consuming and a
constraint. Jane also highlighted that at times there were not enough equipment for all students to
use so they often had to share, and experiments could only be repeated once. It was evident that
time and resources were important challenges teachers often experienced.

4.4 Recommendations

Both participants provided insightful recommendations to the Ontario Ministry of
Education Science curriculum, and to teachers to alleviate their challenges and greater support
student learning in science education. The recommendations were divided into Teacher Support,
and Curriculum Improvements.

4.4.1 Teacher Support

It seems that there is a need for principals and administrators to provide greater support
for teachers. Robin reinforced this by declaring, “We need principals and administrators further
up the team to understand the importance of science, they need to be more involved, they need to
be willing to give more time to it in the curriculum.” She also adds that her school board
mandates too much time into literacy, which she believes to be unnecessary. Robin emphasized,
“…it’s not needed because literacy is in every subject and what we need to be doing is teaching
our teachers *how* to integrate literacy into absolutely everything much more consciously so we can spend more time on other subjects.” Jane also mentioned that the focus in elementary schools was math and language. Robin further stressed the need for greater funding and recognition in science. She compared the current math strategy in many Ontario school boards on implementing greater math specialists as a general consensus for all subjects and expressed:

We need to have highly trained teachers for all of these things, not just math, not just language. We need to have highly trained teachers for all of these things, science, everything. So invest in getting the proper teachers. We need to invest the money in our teachers, to train them to be really good experts at whatever they’re teaching, and use those skills much better than what we’re doing now.

Similarly, Jane also highlighted the need for teacher support in terms of workshops and professional development. She elaborated:

Teachers need to go to workshops where we can actually see it in action. It needs to be practical. Inquiry they go and tell you to ask these questions…but again show me an inquiry unit that you did with your class and I want to see like how did you start it, what were all the steps throughout the entire process, and how did you end it. Just document it all, that’s what teachers want to do, and be honest with us about your challenges, just because you try an inquiry project, doesn’t mean you’re going to be an expert. I think the problem when you go to these workshops, is there’s nothing concrete, or very little that’s concrete.

Jane articulated that workshops could be more useful when teachers can see how they can implement strategies, and see it in action. Overall, the need for greater support for teachers in
science was strongly conveyed in terms of administration, greater funding, improved professional development workshops, and trained science specialist teachers.

4.4.2 Curriculum Improvements

Both participants expressed varying and insightful perspectives for improving the Ontario Science and Technology Curriculum. Robin expressed her frustration with how the science curriculum is organized:

I like the big ideas, and I like how it’s set up when you’re developing your units, here are the big concepts you have to think about. I like that, but…the reality is, teachers start with expectations number one, expectation number two, and expectation number three, and it’s so not well explained how you are supposed to take all these ideas and put it together into a coherent unit to study. I also firmly firmly believe, they took the skills and put them further down the curriculum, and put the concepts at the beginning, so the first expectations you hit, are the concepts…but you can’t answer those questions if you don’t have the skills.

This quote explained that the big ideas in the curriculum are great, however, how the big ideas can be infused throughout the unit should be stated more explicitly in the curriculum document. Robin believes that the curriculum should place a focus on skills first and then inquiry after, she sustained, “…because you can’t do good inquiry without those basic skills.” Jane also expressed a concern regarding inquiry in the Ontario Science curriculum. She stated, “…with social studies they have that inquiry process embedded into the curriculum…” and explained how the specific expectations have an inquiry section to guide the overall expectations for a unit. The ideas the teachers shared on improvements for the current The Ontario Curriculum, Grades 1-8: Science
and Technology, calls for a curriculum reform that could benefit science teaching for teachers and student learning.

4.5 Conclusion

Although the participants had different conceptions of scientific literacy, both participants expressed the importance of scientific literacy in fostering critical thinking, problem solving, and life skills that can be transferred outside of science education. Similarly, hands on and inquiry learning were a repeated teaching pedagogy both practiced by teachers and used effectively in science teaching. The complexity of these findings also further emphasized similar challenges teachers experience and the recommendations for support and curriculum improvements. Principals and administrators need to provide greater support to teachers in science teaching. There is a need for trained science teachers, or science specialists in schools and implications for an Ontario Science Curriculum reform. Success in science education and scientific literacy development is greatly dependent on teacher instruction and student learning experiences. These findings have offered insight on the significance of educators’ perspectives on teaching science, and how science education can be improved for students, so that they may develop transferrable life skills through scientific literacy. The implications for these findings, recommendations and areas for further research will be explored in the next chapter.
Chapter 5: Implications

5.0 Introduction to the Chapter

The purpose of this study was to explore how teachers developed scientific literacy and the challenges they experienced in science teaching with the hope to gain a better understanding to improve student learning. Scientific literacy is a goal of curriculum standards of many countries (Dillon, 2009) and of the current Ontario Science and Technology Curriculum (Ministry of Education, 2007). The primary question guiding this study was: What are the challenges that Ontario Junior/Intermediate science teachers experience when teaching science to develop scientific literacy skills pertaining to scientific literacy? The findings across Ontario elementary educators suggest that teachers understand scientific literacy as an important outcome of science education, and the development of scientific literacy is dependent on teacher practice. In this chapter, implications of this study will be explored, with an overview of the key findings, proceeding with broad and narrow implications, study recommendations and areas for further research.

5.1 Overview of Key Findings

The key findings examined in Chapter 4, offered insights by the participants into their understanding of scientific literacy, their science pedagogy, the challenges related to science teaching, and how their teaching practices in science can be better supported and improved. Through the interview questions, the participants reflected on their beliefs in science education, its goals and how scientific literacy development is translated into the classroom. The findings strengthen current literature found in Chapter 2 related to the challenges teachers experience, and current science pedagogies, such as inquiry-based learning. Nevertheless, the participants offered insights that were beyond the scope of the research literature review. Ontario elementary
educators in this study suggest that improvements in the current 2007 Ontario Science and Technology Curriculum for Grades 1-8 could be made to better support teacher instruction and student learning in science. Greater support from school staff and administrators were also suggested to alleviate some of the challenges teachers experience in science teaching. Four overarching themes emerged from these findings: teacher perspectives of scientific literacy, teaching practices, challenges, and recommendations. The evaluation and implications of these findings will be explored in further depth in this chapter.

5.2 Implications

The implications of this study are valuable in providing directions for improving science education outcomes in students and enhancing teaching practices for teachers. With improvements in science education outcomes, scientific literacy development can be effective and prepare students with the skills to think and be responsible citizens in a modern world that is increasingly impacted by science and technology (Vieira & Tenreiro-Vieira, 2016). These findings have implications for the educational research community at large, and implications for educators, teachers, school administrators, and staff. Lastly, these implications are valuable for my future as a science teacher and in my future educational endeavours.

5.2.1 Broad: The Educational Research Community

At the broad level, findings from this study indicate that regardless of the various definitions that teachers conceptualize of scientific literacy, they have similar beliefs on the outcomes of science education. The term “scientific literacy” is actually quite ubiquitous. The synthesis of the participants’ understanding of what scientific literacy means resulted in the following definition:
Scientific literacy is the ability to question the world around us, use critical thinking to make informed choices and be responsible citizens. It includes the ability to question and justify explanations for certain phenomenon or observations. Scientific literacy includes an active component, the ability to use these skills to problem solve and evaluate the best solution in a given situation.

Both participants recognized that scientific literacy encompasses skills that can be cultivated in science education and transferred outside of the classroom into lifelong skills. This implication presents that perhaps “scientific literacy” is just a popular term often used in science, but defines education goals across other subjects and disciplines. Scientific literacy encompasses the skills such as critical thinking and questioning that are also fostered in other subjects like math or social studies. However, science education is often perceived as the most suitable or primary place to develop these skills.

This study also found that the more knowledge teachers had in science, the greater their self-efficacy was in teaching. This indicates that greater professional development workshops are recommended in science and inquiry teaching, to enhance teacher instruction, especially for those who do not have a science background. While teachers used a number of different pedagogies in science, inquiry-based learning was a common method found by the participants. Inquiry-based learning is a teaching method that can be embedded with other teaching methods concurrently. However, as one of the participants in the study stated, fostering effective and meaningful inquiry-based learning can be challenging. One of the challenges teachers found was the process of inquiry after the questioning process.

It was also found in this study that the participants did not include cultural diversity into science education, although they may be aware of the importance of incorporating Indigenous
perspectives and ways of knowing in today’s curriculum. The *Ontario Curriculum, Grades 1-8: Science and Technology* includes a focus on Canadian contributions and does not include other diverse factors of knowledge contributed to science. This implies that science education in Ontario is still predominantly taught through a westernized lens, and we must broaden these views of science. Hodson (1993) has stated:

> Recent research into children’s learning in science emphasizes the need to begin teaching with the knowledge and experiences of the learners and build from that base to assist the development of their understanding of the world. As yet, however, there has been little research focusing on the different perspectives and experiences of children from different cultural groups (p.686).

This research, which dates back to 1993 is still relevant today because there remains a lack of multicultural science education. A science education that incorporates cultural factors of knowledge is important because it is student-centred, it draws on student experiences and strengthens learning.

> Overall, scientific literacy is a specific term that summarizes the goals of science education, but in practice is very broad. Both participants did not specifically state how they developed scientific literacy skills in teaching, but that the skills pertaining to scientific literacy are fostered in their teaching practice. Both participants employed and emphasized the use of inquiry-based learning in science teaching, however both lacked to include cultural knowledge or diverse contributions to science.

5.2.2 Narrow: Professional Identity and Practice

Scientific literacy is a goal of science education that I strongly believe in and would foster as a future teacher. Now, I believe that the broad definitions of scientific literacy and the
transferrable outcomes developed in science education are goals for all education. This includes developing critical thinking, the ability to question, use of evidence to draw and justify conclusions, and the ability to use these skills to make informed choices and evaluate information presented in our everyday lives. This study has shown that there is no one particular or distinct way to develop scientific literacy in students. Different teachers will employ different kinds of teaching methods. However, teachers seem to experience similar challenges in science education. One of the dominant challenges teachers experience is their ability to teach science successfully because of their limited knowledge or experience. This study demonstrated that self-efficacy in teaching is connected to how much knowledge a teacher has in science. As a student teacher with previous practicum experiences, I resonate with this finding. I find that when I am not familiar with the subject or have limited background in a subject area, my confidence to teach that subject is low and I find it challenging. This implicates for me as a future teacher that I have to take initiatives to learn new things about the subject. One of the ways to overcome these challenges is to have continuous professional development, and be proactive about new ways of teaching and learning. As a researcher, this implicates for me to stay current on new research about education and understand how I can use that and translate it into practice. Throughout this study, I have gained a breadth of perspectives about science education. The lack of inclusion of culture and diversity in science education is also significant to me, and as a future teacher, I will work towards including different perspectives in science. These implications for me as a future teacher aims to help students develop skills pertaining to scientific literacy, and to provide a rich educational experience for students.
5.3 Recommendations

As an outcome of this study, I provide recommendations for schools, teachers, administrators, and the Ontario Ministry of Education to address the concerns of the challenges that both participants experience in science teaching. To improve science education in schools and classrooms, it is imperative that administrators, principals, and staff provide greater support to teachers. At the school level, support is needed in terms of funding, maintenance, and organization of science equipment. To improve science teaching and methods, teachers need additional professional development workshops, where they can see practicum applications. For example it would be helpful if teachers could see a whole inquiry unit process and explore ways to improve inquiry within their own classes. Professional development workshops could also fill the gap for teachers with limited science background and make the approaches of science teaching more feasible for them. This study also recommends that greater teacher specialists in science be invested in schools.

For the Ontario Ministry of Education, a reform of *The Ontario Curriculum, Grades 1-8: Science and Technology* is recommended. Both participants expressed recommendations for the curriculum to benefit teachers and student learning. First, it is suggested that the curriculum be improved in explaining how the big ideas fit in a coherent unit. Second, it was highly recommended that the expectations concerning critical thinking skills be of focus first, and then understanding concepts afterwards because students need to develop skills in order to understand the concepts. It is also recommended that inquiry be embedded and explicitly defined throughout the science curriculum to guide the overall expectations for a unit. In this way, teachers can use the curriculum to teach more effectively and increase learning outcomes.
To support the development of critical thinking and scientific literacy skills, teachers should take on a greater role as a facilitator rather than a teacher during science lessons. For example, teachers facilitate and guide students through the inquiry process. Teachers need to provide opportunities for students to question, analyze, and evaluate information presented to them under a critical lens using real life scenarios, or case studies. It is imperative that teachers incorporate STSE in science education and explore issues of social justice within a science context. Teachers should also encourage and value diverse perspectives that students bring into science. Science education should allow students to be engaged and participate in the world around them. Students must be able to recognize science and understand its relationship to other areas and its applications in their everyday lives. The goal of developing critical thinking and scientific literacy in students is so that they may use this knowledge and skills beyond the classroom and are equipped to make informed decisions and respond to the challenges of the 21st century.

5.4 Areas for Further Research

This study has brought to light some questions that were raised through this research and the need for further research in other areas to help develop the body of knowledge on scientific literacy, science education, and teacher challenges. Some questions that were raised include:

- Should the concept of scientific literacy be explicitly explained to students to help them develop scientific literacy?
- How can teachers incorporate student knowledge and cultural values in science education, and is it important?

Important areas for future research include culturally relevant and responsive pedagogy approaches in science education, and challenges of a diverse or multicultural science education.
5.5 Concluding Comments

As a beginning science teacher with a Bachelor of Science background, providing a science education that fosters skills of scientific literacy is valuable and important to me. In this study, findings showed scientific literacy as an important outcome of science education. However, this study highlighted some of the common challenges that teachers experienced in teaching science, some of the concerns related to the current 2007 Ontario Science and Technology curriculum, and the need to better reflect teaching practices for effective learning. The skills developed in scientific literacy are pertinent to our modern world, and it is important that teachers have a high self-efficacy to provide a science education where students can be successful.
References


Appendix A: Letter of Consent for Interview

Date:

Dear _______________________________,

My Name is Charlene Pan and I am a graduate 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 Master degree program involves conducting a small-scale qualitative research study. My research will focus on the challenges and development of scientific literacy in classrooms. I am interested in interviewing teachers who have experience teaching science in elementary schools. I think that your knowledge and experience will provide insights into this topic.

Your participation in this research will 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 Master of Teaching Research Project, which will include a research paper, as well as informal presentations to my classmates and/or potentially at a conference or publication. I will not use your name or anything else that might identify you in my written work, oral presentations, or publications. This information remains confidential. The only people who will have access to my assignment work will be my research supervisor and my course instructor. You are free to change your mind at any time, and to withdraw even after you have consented to participate. You may decline to answer any specific questions. I will destroy the audio recording after the paper has been presented and/or published which may take up to 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. Thank you very much and I appreciate your participation.

Sincerely,

Charlene Pan
Email: charlene.pan@mail.utoronto.ca

Course Instructor: Dr. Rose Fine-Meyer
Email: rose.fine.meyer@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 Charlene Pan 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 Questions

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 teachers conceptualize scientific literacy and the effects of current pedagogies used in science teaching for the purpose of alleviating the challenges teachers experience when teaching science and increasing the development of enduring scientific literacy in students. This interview will last approximately 45-60 minutes, and is composed of approximately 26 questions. The interview protocol has been divided into 4 sections, beginning with the participant’s background information, followed by questions about teacher perspectives on scientific literacy, then their experiences and practices, and concluding with questions regarding supports, challenges, and next steps for teachers. 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?

Section A - Background Information

1. What grade(s) and subjects do you currently teach?

2. How long have you been teaching for? How long have you been teaching science?

3. Is your teachable in science? If not, what is your teachable?

4. Are you involved with any extracurricular activities, volunteer, or school clubs relating to science (such as Eco Clubs, Science Clubs, afterschool science help)? If so, can you please tell me about your experience in these activities?

5. Have you been to any workshops throughout your career that have been related to teaching science (such as Inquiry, Knowledge Building Workshops)? If so, were they helpful in informing about your teaching? What did you learn from these?

Section B – Encounters and Teacher Perspectives on Scientific Literacy

6. What were your experiences with learning science as a student in your elementary years? How did that influence your attitude towards science later on?

7. Did these experiences affect your decision to become a teacher and if applicable, a science teacher?
8. What are some of the differences you observed in science teaching when you were a student in your elementary years compared to the present?
   a) How does that compare to how you instruct science in your classroom?
   b) Are there any similarities, if so what are they?

9. What is your understanding of scientific literacy? How does this impact your teaching?

10. Is the development of lifelong scientific literacy important to you? If so, why?

11. What do you believe are the goals of scientific literacy?
   a) Do you think this is reflected in the Ontario Science and Technology Curriculum?
   b) Is there anything missing that you feel the Ontario Science and Technology Curriculum does not address but should?

Section C - Teacher Practices and Experiences

12. What is your teaching pedagogy and how do you incorporate that into your science teaching?

13. What current pedagogy approaches do you use in teaching science? (For example, integration of multiple subjects, inquiry, place-based learning, etc.)

14. Have you used inquiry-based learning in your science instruction?
   a) How did you use inquiry?
   b) How effective did you find inquiry-based learning to be?

15. How do you foster scientific literacy in the classroom?

16. If applicable, in the course of your teaching career, did you notice any differences in academic performance and attitudes towards science across different grades that you’ve had experience teaching? (For example, a decrease in attitudes towards science after Grade 6)

17. Do you accommodate for any cultural factors of knowledge that students of diverse backgrounds bring to the classroom in science? If so, how?

18. What are your strengths and weaknesses in teaching science?

19. How do you assess or know that students have gained the skills pertaining to scientific literacy such as critical thinking and/or problem solving skills?

Section D - Supports and Challenges, and Next Steps

20. What are the challenges and limitations you have encountered in teaching science? How did you respond to these challenges?
21. What are some of the learning challenges you have observed in students when learning science? How do you provide support for them?

22. What kinds of resources, and/or professional development and/or online programs are there to support science teaching for teachers?

23. How would you like to improve in your science teaching?

24. What do you believe still needs to be done to alleviate the challenges of science teaching for teachers and learning for students?

25. What do you believe can be done to improve the development of scientific literacy in elementary school students?

26. As a beginning teacher entering into the profession with a teachable in science in the Junior/Intermediate sector, what advice or recommendations can you give me?

Thank you for your time and participation in this research study.