TEACHING SCIENTIFIC LITERACY

PRACTICES OF INTERMEDIATE TEACHERS IN THE DEVELOPMENT OF LIFE-LONG SCIENTIFIC LITERACY

by

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A Major Research Project submitted in conformity with the requirements for the degree of Master of Teaching

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Abstract

Science is important in the everyday lives of Canadians, but fewer than half of Canadians have the basic level of scientific literacy required to interpret the scientific matters they are exposed to daily. The intermediate grades (7 to 10) are often the last stage at which science education is mandatory and thus the last guaranteed opportunity for teachers to foster enduring scientific literacy in their students. In this study I asked: how are a small sample of Canadian intermediate teachers developing life-long scientific literacy among their students? Using semi-structured interviews I spoke with five science teachers; three from Alberta and two from Ontario to provide a greater cross-country perspective. After analysing the interview transcripts for codes and parsing out themes I found the broad and varying definitions of scientific literacy make it difficult to determine when and how scientific literacy is being taught. While this small selection of teachers identified a variety of approaches for teaching scientific literacy they struggled with how to assess scientific literacy. Moving forward I suggest that a concerted effort be made to clarify the meaning of scientific literacy so educators can develop more specific goals when teaching scientific literacy and assessing for its development.

**Keywords:** Scientific Literacy, Teaching Practices, Science Education
Acknowledgements

First, I would like to thank the Social Sciences and Humanities Research Council for supporting this research through the Canadian Graduate Scholarship – Master’s.

Next I would like to thank my supervising professors, Dr. Angela MacDonald-Vemic and Dr. Eloise Tan. Your guidance and support has been instrumental in the development and completion of this project. Without you my journey through the world of qualitative research would have been much more tumultuous. Thank you also to my other professors at OISE and the OISE educational community as a whole for providing support to all those in the Master of Teaching program, including myself. I would also like to specifically thank the JI252 cohort of 2016: it has been a tremendous pleasure working beside you all through the course of the program and this project. Thank you also to the participants of this study: this work would not exist without your contributions.

Thank you to my family for your continued love and support. Thank you to all families, old and new: Lipsett, Douglas, Selby, Hoffman, and Russell have all helped me through these past two years. Thank you especially to Dad and Cindy for always checking in on me, and believing I can achieve anything. And a big thank you to Justen, my partner in crime, my constant support: together we will take on the world – for science!
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Chapter One: Introduction

1.0 Introduction

Every day Canadian citizens, in the process of interacting with their immediate environments, come into contact with science. From the nutritional science of the food they eat, to the environmental connotations of their energy choices, to the mechanics of their modes of transportation, every moment is steeped in scientific relevance. However, according to a recent report by the Council of Canadian Academies (2014), only 42% of Canadians have basic scientific literacy, defined by the Council as the possession of a basic science vocabulary and a general understanding of the nature of science. This means the majority of citizens, including graduates of Canadian school systems, lack the scientific literacy to properly assess the issues they are presented with on a daily basis.

The prevalence of scientific illiteracy is particularly concerning considering the current state of science in Canada. While Canada promotes itself as a global leader in science and technology (Berry, n.d.; Council of Canadian Academies, 2014), the country is experiencing declines in scientific achievement in our schools and declines in funding for science research in our laboratories (Berry, n.d; Statistics Canada, 2014). Simultaneously, Canada has garnered international scorn for the so-called “War on Science” in which the former Canadian Harper Government was widely perceived as “muzzling” government scientists by regulating their communications with the media and therefore the public (Casassus, 2014; Greenwood, 2013; Linnitt, 2014). If Canada is to maintain its position as a respected leader in science and technology these issues must be addressed. In the context of a democratic society with individuals voting not only with their ballots but also with their voices and
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dollars, it is imperative citizen scientific literacy, and as an extension good citizenship, is a priority (Citizenship and Immigration Canada, 2012; Grayling, 2013; Thomas & Durrant, 1987). Science is an integral part of our society, but if most of our citizens are scientifically illiterate, we risk misdirection and the stifling of societal progress (Council of Canadian Academies, 2014).

Grade schools are the primary source of formal scientific education in Canada, and thus have a key role in the development of scientifically literate citizens. Across the country, science curricula highlight the importance of scientific literacy. The Ontario Grades 1-8 Science and Technology Curriculum begins with a definition of scientific literacy as being able to critically evaluate scientific reports in the media (Ontario Ministry of Education, 2007). Furthermore, the first goal of the curriculum is “to relate science to technology, society, and the environment” (Ontario Ministry of Education, 2007, pg 3). The Alberta junior high science curriculum stresses the importance of developing a thorough knowledge of science and its relationship to technology and society (Alberta Education, 2014). Further examples across the Canadian curricular landscape abound. With the overarching goals of Canadian science curricula being linked to critical thinking and connecting science to the world around us, it is clear a primary expectation of science teachers is that they foster scientific literacy in their students. Furthermore, aligned with a system designed to encourage responsible citizenship, it is also expected science teachers will foster a level of scientific literacy in their students that will endure outside the classroom and beyond graduation.
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If a primary goal of grade school science education is to develop scientific literacy, it is important for educators to be mindful of the outcomes of their teaching practices, and include assessment for the development of scientific literacy in their students. In some cases, upon assessment it has been found that extensive exposure to science does not guarantee the development of scientific literacy: in an Alberta study of science-streamed high school students, few participants were able to integrate their background beliefs with scientific texts, which is one measurement of scientific literacy (Phillips and Norris, 1999). This shortcoming in scientific literacy, despite completion of multiple science classes, merits further investigation into the best practices to develop scientific literacy in Canadian schools (Phillips & Norris, 1999). The disconnect between science exposure and enduring scientific literacy is highlighted when adults are surveyed, for despite the fact over 90% of Canadians self-report interest in new science discoveries, a commonly heard view of science is as a lofty field which laypeople cannot understand (Council of Canadian Academies, 2014; Grayling, 2013).

If the majority of scientific exposure and education comes in the form of grade school education, and if adult scientific literacy needs to be improved, grade school science education is an important area to investigate.

The gap between science exposure and scientific literacy is incredibly important to address in the information age. With access to information on any topic at the click of a button, the ability to critically interpret information and make informed decisions is essential to the advancement of society as a whole. The suggested benefits of citizen scientific literacy are wide ranging, and include increased national prosperity and influence as a result of increased scientific participation and development, increased societal unity from mutual understanding of issues, and stronger democracy supported by broadly informed decisions.
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(Thomas & Durrant, 1987). Scientific literacy is also more than understanding and utilizing scientific thought and processes: it is the valuing of science as well (Fives, Huebner, Birnbaum, & Nicholich, 2014; Thomas & Durrant, 1987). When citizens and their governments do not value science there are increased risks for budgets cuts for research such as those recently observed in Canada, with particular targeting of fields that do not have an immediate clear impact on society but are often the source of our greatest innovations (Hoag, 2012). Just as science is important to the daily lives of Canadians, scientific literacy is vital to participatory democratic citizenship.

1.1 Purpose of the Study

The purpose of this study is to explore the practices of intermediate teachers that support the development of life-long scientific literacy. Interest in science, if not cultivated early, is rarely developed in later life (Gibson & Chase, 2002). The intermediate years mark the time that students begin to receive instruction from field-specific teachers, as well as when interest in science and school in general declines (Fives et al., 2014; Gibson & Chase, 2002; Osborne, Simon, & Collins, 2003). Thus the intermediate grades are of particular relevance as it is at this stage we find a group of students who require positive experiences in science to maintain scientific engagement prior to reaching the age of majority when they will gain greater civic and social responsibilities. For this reason it is imperative intermediate students be informed of the relevance of science in everyday life, and they learn to recognize and value science not only in terms of innovation and intellect, but also for its role in social and political matters.
A further purpose of this research is to report and share practices Canadian intermediate teachers are using to develop scientific literacy in their students, so that these practices may be disseminated and thereby inform the instructional practices of more teachers, and support educators in their teaching of this aspect of the curriculum. It is my hope that these findings may also support teachers in a broader context, as development of scientific literacy also extends into other areas of the curriculum including, but not limited to, math, literacy, health, and social studies.

The cultivation of scientific literacy in students is important for Canadian society. Given that Canada is confronting many national and global issues that have enormous scientific input and consequence (e.g. health, energy, climate, and industrial matters), investigation into best practices for scientific literacy instruction has the potential to help prepare teachers and their students for confrontation with an uncertain future and challenges on the horizon.

1.2 Research Questions

The primary question guiding this study is: How are a small sample of Canadian intermediate teachers developing life-long scientific literacy among their students? Sub-questions to further guide this inquiry include:

- How do these teachers conceptualize scientific literacy, in theory and in practice?
- What range of instructional approaches are these teachers implementing to develop scientific literacy?
- How do intermediate science students respond to these pedagogies?
• What indicators of learning do these teachers observe? How do these teachers assess scientific literacy for short and long term development?

• What resources and factors support and hinder these teachers in their commitment to teaching scientific literacy?

• How did these teachers become interested in scientific literacy? What experiences prepared them for this work?

This project also aims to raise awareness of the importance of scientific literacy, and inspire teachers to be mindful of their own beliefs and practices in the teaching of science.

1.3 Background of the Researcher

The topic of scientific literacy is particularly interesting to me, stemming out of my experience as an academic researcher while completing my Master of Science in Physiology. In that time I was made aware of two troubling things: 1) that most non-scientists will approach science as “too complicated for them” before even attempting to understand a topic, and that 2) scientific educations does not prepare students for careers in science.

I was an enthusiastic learner for most of my life, and became particularly interested in the sciences when the field-specific concentrations were offered separately in high school. Proficiency in biology and chemistry lead me to an undergraduate degree in Zoology. Zoology is a multifaceted field than encompasses evolution, ecology, anatomy, physiology, and more, and my B.Sc. provided me with a thorough overview and understanding of many topics. I also was able to do a research project, culminating in a publication of my findings in a peer-reviewed journal. My concerns about scientific education came forward throughout my subsequent master’s program in physiology. First, I often found that many people in
non-scientific fields view science as inaccessible to them. Friends and family responded to my thesis topic with comments like “that is too complicated for me” before I even had the opportunity to explain it to them. This disheartening response made clear to me that many people do not maintain scientific thinking and confidence after graduation, if indeed they ever developed it. What was further distressing is that I myself was ill-prepared to truly consider and critically question my topic of investigation as is expected in professional science, and therefore struggled through my M.Sc.. This brought me to question our system of scientific education: Why are high school graduates lacking confidence in the face of science? And what can be said for the scientific literacy of most citizens if even scientifically motivated students are not developing the desired scientific literacies?

As an individual motivated by communication, I have now pursuing a teacher education program, where I am specifically interested in what can be done to better science education, and to elucidate the practices that can lead to strong, scientifically literate citizens. My scientific education impressed upon me the value and utility of science, and I want to see scientific values and skills made accessible to all, for the betterment of society.

1.4 Overview

This research project is organized into five chapters. Chapter One: Introduction includes the introduction to the problem and purpose of the study, as well as research questions and the researcher’s background which lead to the investigation of this topic. A review of the relevant literature is covered in Chapter Two: Literature Review. Chapter Three: Research Methodology provides the methods used in this study including information about the participants, data collection, and limitations. The findings of this research project
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are detailed in Chapter Four: Findings. Chapter Five: Discussion includes what was implications of the findings, corresponding recommendations and future directions for research. References and Appendices are found at the end.
Chapter Two: Literature Review

2.0 Introduction

In this chapter I review the literature in the areas pertaining to scientific literacy, intermediate students, and science teaching practices. More specifically, I review the varying definitions of scientific literacy, and consider what aspects of scientific literacy require focus in the development of empowered citizens. Next I consider the understanding of the intermediate student and why they are of particular interest in terms of science attitudes and achievement and therefore scientific literacy. Finally, I overview some of the practices that have been suggested, tested and implemented to “improve” scientific education and therefore improve scientific literacy.

2.1 Scientific literacy

Scientific literacy does not have one universally accepted definition, but rather a number of proposed and related definitions. One definition that hints at this range comes from the Council of Ministers of Education (1997), who indicate that scientific literacy involves a combination of science related aspects including attitudes towards science, skills and knowledge needed for the development of inquiry, problem solving, and decision making, with the added idea that these aspects support lifelong learning and an enduring sense of wonder. This definition is helpful in that it includes knowledge, skills, attitudes, and cognitive processes to emphasize the many facets of scientific literacy. However it presents a broad idea and is perhaps difficult to conceptualize.
An alternative definition for scientific literacy looks at it as a two-pronged concept. Phillips and Norris (2003) utilize such a definition, splitting scientific literacy into fundamental and derived aspects. The fundamental aspect encapsulates the concepts and skills related to all reading (i.e. basic literacy), and the derived aspect refers to science content knowledge (Phillips & Norris, 2003). Using fundamental and derived subsets of scientific literacy emphasises the importance of both universal and field specific knowledge, but lacks an element about the skills and processes specific to science and scientific reasoning.

Roberts (2007; 2011) also conceptualizes scientific literacy as a two-pronged concept, but more in the sense of viewing it as two distinct versions rather than as a bidimensional concept. Version one is to understand science as a scientist, and version two is to have a broad understanding of science situations relevant to everyday civilian life which is needed in order to make informed decisions (Roberts 2007; Roberts 2011). These definitions are interesting in that they separate the professional- and lay- elements of scientific literacy, an aspect not brought to the forefront in many educational discussions of the topic. These definitions, however, continue to lack specificity and thus may be difficult to evaluate without further criteria.

Scientific literacy is sometimes described as a much simpler concept, particularly for purposes such as large scale surveys. In these cases, scientific literacy can be defined as the basic level of science understanding to interpret science reports in the media (Council of Canadian Academies, 2014). Such simple definitions are helpful in their measurability, providing a clearer cut off for what entails acquisition or lack thereof. However, again they
do not include some of the other facets championed to be considered in scientific literacy, such as attitudes towards science.

Further definitions still are found in educational resources, often incorporating elements mentioned above. The Alberta junior high science curriculum focuses on the importance of scientific literacy in terms of the development of knowledge, skills and attitudes, as well as the importance of lifelong learning (Alberta Education, 2014). The Ontario elementary science and technology curriculum instead draws on a definition that focuses on the importance of interpreting science media, and the ability to interpret the contained information to make decisions (Ontario Ministry of Education, 2007). Perhaps the most comprehensive definition that is also used directly in assessment is that used by the Program for International Student Assessment (PISA), which is an international test administered by the Organization for Economic Co-operation and Development (OECD). PISA tests for, among other things, science achievement in countries around the world, specifically assessing scientific literacy in terms of 1) attainment of scientific concepts, 2) ability to use the scientific process to draw evidence-based conclusions, and 3) response to scientific situations found in everyday life (Government of Canada, 2013).

These diverse definitions of scientific literacy both allude to and are discussed in light of a single concept: that a certain amount of understanding of science is required for citizens to be informed and equipped to make important decisions. Governments are further interested in scientific literacy as a measurement of their populations. Scientific literacy is widely thought to be important to the advancement of national and global development, and is therefore sought in Canadian citizens (Thomas & Durant, 1987). While Canada has a high
proportion of scientifically literate citizens in comparison to other evaluated countries, it is disappointing to note that fewer than half of Canada’s population has the most basic level of scientific literacy (Council of Canadian Academies, 2014). A key way to improve our national scientific literacy is to understand how the subject is being breached in our classrooms, which this study will further examine (Lumpe, Haney, & Czerniak, 2006).

2.1.1 Related Literacies

As indicated by the definition used by Phillips and Norris (2003), scientific literacy does not stand in isolation from other literacies. A commonly discussed aspect is that of basic language literacy; that is, the ability to read. Without language comprehension people are unable to access the scientific information available and begin to assess it (Cutilli & Bennett, 2009; Fang, 2006; Fang & Wei, 2010). Language literacy in respect to science also requires the development of some additional skills, as science writing has unique conventions that differ from those of other writing styles and require additional instruction to decode (Fang, 2006). Specific aspects of basic language literacy within scientific literacy will be discussed further below.

Seeing as the world of science and the world of technology often overlap, digital information literacy is a further area to consider in conjunction with scientific literacy. Digital information literacy is the ability to access and interpret information online, and it is important to examine as the interpretation and evaluation of scientific information includes the ability to access resources and assess their reliability (Colwell, Hunt-Barron, & Reinking, 2013). Digital literacy is especially important for the act of inquiry because researching questions, organizing evidence, and developing and communicating explanations all occur at
the crossroads of science and technology (Colwell et al., 2013). While information literacy has been an aspect of interaction with scientific texts for decades, the onset of the digital age has brought with it the need for additional skills of discernment, and thus digital information literacy is classified as a distinct skill (Leu et al., 2005; McEneaney 2006; Reinking 2010). Digital information literacy can be a particularly difficult skill to establish, as digital habits developed outside of the classroom can conflict with sound information practices taught within (Colwell et al., 2013).

Mathematical literacies can also be considered important to scientific literacy. In particular an understanding of statistics has been studied as an important aspect of understanding data, a fundamental element of evidence-based science (Carmichael, Callingham, Hay, & Watson, 2010). Statistical literacy is the ability to interpret and evaluate information with statistical aspects (Gal, 2003). Most studies from the world of science include a statistical aspect, and without a certain level of statistics comprehension there is a risk of misinterpreting scientific findings. However, student interest in statistics is declining leading to fewer students pursuing statistical classes and associated lower statistical, and therefore scientific, literacy (Carmichael et al., 2010).

2.2 Science and the Intermediate Student

Intermediate, in Ontario, refers to students between grades 7 and 10, generally aged between 12 and 16 years old. The comparable grouping in Alberta education is Division 3, which spans grades 7 to 9. Intermediate students share qualities of both junior (Ontario grades 4-6) and senior (Ontario grades 11-12) divisions, often looked upon as young and malleable, while simultaneously being viewed as older and more cognitively active as a
result of increased life and scholarly experience. The intermediate years of schooling are a critical time for developing or sustaining student interest in science before students enter secondary school when science is often fragmented into distinct fields, and whereby students’ frequently have more choice whether to study the full range of fields or abandon the pursuit altogether (Fives et al, 2014; Gibson & Chase, 2002).

### 2.2.1 Engagement

It is in the intermediate grades that interest in science and math are often observed to decline (Osborne et al., 2003; Gibson & Chase, 2002). The importance of engaging students to be able to achieve meaningful learning is an aspect of many teachers’ educational approaches (Oliviera et al., 2012). Intermediate students who have positive experiences with science are more likely to maintain positive attitudes and engagement than peers without comparable experiences (Gibson & Chase, 2002). It is important to further note that foundations for a positive attitude towards science are thought to be laid prior to middle school (grades 6-8), and a focus in the intermediate grades is to maintain positive attitudes more so than initiate them (Gibson & Chase, 2002).

### 2.2.2 Academics

Achievement in academics is often observed to decline in the intermediate grades, in strong correlation to decreasing interest in various subjects, and science is not exempt from this trend (Schiefele & Csiksentmihalyi, 1995). Declines may be related to further factors. The intermediate grades often include a transition from “learning-to-read” to “reading-to-learn” which can give rise to new issues (Chall, 1996). This transition may lead to difficulties, as intermediate students often struggle with the interpretation of science texts.
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even after having established basic literacy (Berman & Biancarosa, 2005). Intermediate students require different supports to sustain achievement than were provided in the elementary grades, and these should be clearly identified and implemented to encourage continued learning (Fang, 2006).

Students in middle school have also been found to be resistant to certain interventions to break prior habits that conflict with scientific literacy. For example, in a study on digital literacy, students that were taught proper online search practices were able to explain the best way to perform searches, but inevitably fell back to their previously used strategies after a period of time (Colwell et al., 2013). From this we can see that the promotion of enduring understanding and application of science is an important aspect of intermediate education.

2.3 Science Teaching Practices

There are many methods and philosophies guiding science teaching. In one survey of science education, instructional approaches to teaching science included the ideas of relevance, engagement, inquiry, differentiated instruction, collaboration, homework, and curriculum integration (Oliveira et al., 2012). Below I focus on a few of these areas that are either commonly described or commonly used. It should be noted that many of these practices are evaluated in studies by immediate student performance and not necessarily for enduring understanding.

2.3.1 Inquiry

Inquiry is possibly the most widely advertised method of science teaching in today’s education field. Inquiry involves engagement in science questions, the prioritization of evidence, and the development, justification and communication of explanations (Loucks-
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Horsley & Olson, 2001). The idea behind inquiry is that students can improve their scientific literacy by experiencing the scientific process (Mackey & Culbertson, 2014). Inquiry activities are often categorized in an ascending scale based on the aspects of inquiry that students are meant to generate themselves: confirmation inquiry where all aspects are known initially; structured inquiry in which students discover the solution through the activity; guided inquiry where students choose the methods and discover the solution; and open inquiry where students generate all aspects of the activity including the question (Bell, Smetana, & Binns, 2005) Many studies have indicated that the use of inquiry increases student achievement (Chang & Mao, 1999; Endler & Bond, 2008; Stohr-Hunt, 1996).

Inquiry, despite widespread support, does have some noted shortcomings. Teachers who describe their science teaching as inquiry-based sometimes do not implement inquiry to its intended end, rather stepping in to assist in such a way that can compromise the students’ inquiry process (Colwell et al., 2013). Furthermore, the level of inquiry intended does not always match the level observed in classroom. For example, a teacher who sets out to run a lesson based on open inquiry can easily find themselves in the role of “answer-provider”, and thus students are not seeking out information independently, and perform an inquiry that is more confirmatory in nature (Colwell et al., 2013). Open inquiry can also fall short if not scaffolded well, leaving students feeling lost and unmotivated (Colwell et al., 2013). Finally the strength of inquiry-based science education is more established in short term outcomes, with many studies examining science achievement immediately after the use of the inquiry intervention (e.g. Colwell et al., 2013). There is a need for evaluation of the role of inquiry-based learning in the development of enduring understandings through the use of longitudinal studies.
2.3.2 Traditional Teaching

Despite the many educational reforms that have been suggested (e.g. American Association for the Advancement of Science, 1993; National Resource Council 1996), there are still many classrooms in which a more traditional method of teaching is used. Traditional teaching generally refers to a set up in which the teacher acts as the master of information, providing content information for their students to absorb and replicate in tests, assuming that replication equals understanding (Renner & Lawson, 1973). Despite a long history of research suggesting that traditional teaching methods are not best practice to develop understanding, surveys indicate that some classrooms still exhibit a high percentage of teacher-dominated speaking time (Hodson & Reid, 1988). Traditional teaching methods may be maintained in different cases for different reasons. Teachers have a tendency to teach as they were taught themselves, struggling to integrate their pre-service training into the classroom. Furthermore, some institutions, notably universities, primarily use traditional teaching as a policy, observing that traditional methods have guided education for years, and that many remarkable individuals are a product of traditional education. Furthermore it should be noted that traditional teaching is viewed by some as a positive option in light of some issues with more constructivist approaches, where students feel unguided, teachers are unsure of their role, and the student-teacher relationship cannot be cultivated without the structure found in a traditional school day (DeCoito, 2000).

2.3.3 Curriculum Integration

Literacy in science comes to the forefront in the intermediate years when students are “reading-to-learn” and therefore expected to have a basic level of literacy (Chall, 1996). However, science writing has many specific conventions and often word usages that differ
from that of other writings, and thus may still require specific instruction to decode (Fang, 2006). It has been further suggested that using trade books (that is, books published for consumption by the general public) to combine literacy and science can expose students to science texts while building up literacy in science (Fang & Wei, 2010; Fang, 2013). Integration of journalism in terms of science journalism practices and the reading of media reports about science is also recommended for the development of scientific literacy, as these journalists represent a group of people who are scientifically informed without necessarily being scientists themselves (Polman, Newman, Saul, & Farrar, 2014). This would further contribute to the development of media literacy, which compromises an entire strand of the Ontario elementary literacy curriculum.

The incorporation of health and arts into science education has also been explored, including the integration of drama, movement, play-based-learning, and physical education (Comia, 2006). In one study, attitudes of grade 7 students towards science were more positive after a unit involving creative movement to teach particle theory (Comia, 2006). While kinesthetic and artistic expression can be viewed as being opposed to the so called “hard” science, it is refreshing to note that the incorporation of these different curricula and learning styles may have positive influences on scientific literacy.

Scientific literacy also lends itself well to broader exploration of topics such as community and citizenship, which are not necessarily encoded in any specific curriculum but are a general focus for many school systems. While the literature about implementation of such practices is sparse, it is widely suggested that development of scientific literacy in populations contributes to national prosperity and influence, better democracy as a result of
better-informed voters, and increased unity due to mutual understanding (Thomas & Durant, 1987). Considering the described benefits of a scientifically literate society, it is reasonable to expect science to play a role in discussion of good citizenship in the classroom. Hodson (2007) goes even further to suggest that scientific literacy is not even necessarily a subject for science class, but one that should be taken up in the context of history, philosophy and sociology, as science is an inherently cultural endeavor and lends itself to discussions of global power dynamics and international issues. Clearly, the utility of scientific literacy in the classroom is widespread, and it need not be confined to the science lab alone.

**2.4 Conclusion**

In this literature review I examined research related to scientific literacy, intermediate student performance and achievement, and science teaching practices. This review emphasized the extent to which science education research has focused on achievement as a result of varying teaching practices and made corresponding statements about gross scientific literacy. It also raises questions about the enduring nature of science comprehension gained in grade school science, and points to the need for further research about the foundations of life-long scientific literacy laid during child and adolescent education.

By focusing on how teachers conceptualize scientific literacy in theory and practice I hope to contribute further to the instructional practices emphasized in existing research, while also underscoring more specific attention to the implications for citizenship learning. This research study approaches the topic of scientific literacy using semi-structured interviews with intermediate science educators in Canada. The study addresses how teachers conceptualize scientific literacy within their classrooms, the practices they use to cultivate
scientific literacy in their students, and how they determine their own success in terms of fostering enduring scientific literacy. By considering how educators identify and express these ideas and concepts, it is my hope to provide better understanding of the process of educating scientifically literate citizens, and from there inform further teacher training and policy development.
Chapter Three: Research Methodology

3.0 Introduction

In this chapter I outline the methods used for this study. The purpose of this study was to explore the practices of Canadian intermediate teachers that support the development of enduring scientific literacy. This was achieved through a qualitative study using semi-structured interviews with five intermediate (grades 7-10) science teachers; three from Alberta and two from Ontario. First, a review of pertinent literature was conducted (see Chapter Two: Literature Review). Interviews were recorded electronically, transcribed, and coded for themes. Data collected from the interviews were then interpreted and discussed in light of the literature. The strengths and weaknesses of this methodology are briefly examined before concluding the chapter with a summary of the methods and a preview of upcoming chapters.

3.1 Research Approach and Procedures

This study utilized a qualitative research approach using a review of pertinent literature and semi-structured interviews with intermediate science teachers. Qualitative research is valuable as a research approach because it provides an opportunity to explore and gain a detailed understanding of complex problems and issues when useful measurements may be difficult to make or interpret (Creswell, 2013). In education in particular there is a long history of interview-based qualitative research being used to better understand the views of both educators and pupils (Donaldson, 2000; Moallem, 1994; Reiser & Mory, 1991; Savenye & Robinson, 2005). Research of a qualitative nature has numerous strengths, including the ability to identify differences between how policies and resources are intended to be
implemented compared to how they are experienced in practice, and can provide deeper insight into the views and feelings of participants (Hammersley, 2000).

Considering the above, a qualitative approach was used for this study in order to gain a deeper understanding of teachers’ conceptualizations and practices in their own science teaching and how that influences the development of enduring scientific literacy in their students. Using a qualitative approach further suited this study as it aims to provide an understanding of the current state of scientific education without any manipulation of variables (Savenye & Robinson, 2005).

3.2 Instruments of Data Collection

Data collection was done through individual semi-structured interviews, conducted in-person, or by telephone in the case of one interview with Casey (see participant descriptions below). Interviews were fitting to this study as the area of interest was teachers’ lived experiences, which cannot be easily summarized in a few words or numbers (Denscombe, 1998). Specifically, semi-structured interviews were chosen as they permit the flow of conversation while still being guided by previously determined topic-specific questions (Carruthers, 2007). By permitting conversational flow, semi-structured interviews allow for the discovery of important situational elements that may not have been considered prior to the interview, and in particular provide a chance to elaborate on information the participant deems important (Denscombe, 1998). Furthermore, semi-structured interviews allow for probing questions and requests for clarification to ensure the interview questions are answered and understood in entirety (Louise Barriball & While, 1994). Overall, semi-structured interviews were fitting to this study in that they provide opportunities for
participants to share their unique views and experiences and thus capture the depth of understanding that qualitative research champions (Carruthers, 2007).

Interviews lasted approximately 45 to 60 minutes, entailing the same set of questions (see Appendix B below), with additional unscripted follow-up inquiries as needed. The questions covered topics relevant to teachers’ conceptualizations of scientific literacy and their teaching of scientific literacy, including the participants’ personal science experience, their instruction and assessment practices, and their beliefs about scientific literacy and scientific literacy education. Interview questions were subject to a review process at the Ontario Institute for Studies in Education prior to their use. Sample questions include “How do you define scientific literacy?”, “How do you assess the development of scientific literacy in your students?”, and “What resources are available to support you in your teaching of scientific literacy?” Such information from these five Canadian intermediate science teachers provided a sample of teachers’ conceptualizations, practices, and resources they use for developing scientific literacy in their students. Questions were not provided to the participants ahead to time in an effort to welcome more organic answers and discourage researched descriptions of scientific literacy.

The interviews were conducted at a quiet location of each participant’s choosing to ensure their comfort as well as clear audio recording. Locations includes participants’ homes, classrooms, and a public library. All interviews were conducted between June and September 2015. Before the interview began I introduced myself to the participant, and outlined the topic as the practices of intermediate teachers in the development of life-long scientific literacy.
Next, the purpose of the interview was outlined: mainly, that the data being collected were for use in a Master of Teaching research project, that participation was voluntary, and that consent could be withdrawn by the participant in part or whole at any time during or after the interview up to the point of publication. Furthermore, I explained that a transcript of the interview would be provided to the participant for overview and confirmation of accuracy, at which time any changes or redactions could be made. An opportunity to ask questions about the project and interview protocol was provided. Every effort was made to ensure the participants were comfortable and willing. Participants were provided a consent form (Appendix A) outlining the above information prior to the interview. Two copies of the form were signed the day of the interview, one to be stored for research purposes and one for the participant to keep for their own records.

Interviews were recorded on a Microsoft Surface 2 using the Sound Recorder App (Microsoft Corporation, version 6.3.9600.20280). Notes were not taken in order to maintain a more natural and open setting for the participant. All questions were asked, generally in order unless a participant asked to return to a question later or a question was fortuitously covered in the process of answering a prior question in which case it was not repeated.

The interview recordings were saved on a password protected Microsoft Surface 2. Only I had access to these files. Interviews were transcribed from the audio recordings into text documents using a verbatim style. Text documents were similarly protected. A copy of each participant’s interview transcript was emailed to them for their overview and approval. All data were stored with the intention to be maintained until submission of this research.
project and any connected publications, up to a maximum of five years, at which point they will be deleted.

3.3 Participants

Five Canadian intermediate science teachers were chosen to participate in this study. Three of these teachers were from Alberta, and two were from Ontario. Teachers from these provinces were chosen to provide a survey of education systems across Canada that differ in industrial and political landscapes. In particular, Ontario and Alberta are often perceived to be in contrast: in population Ontario is large and Alberta is small; Ontario has a manufacturing and services economy, and Alberta has an energy economy; in politics, Ontario is often perceived to be liberal and Alberta to be conservative. These differences often pit these two provinces against each other in the public’s eye (See The Globe and Mail, January 25 2015). These differences can also be brought up in terms of the provinces’ approaches to issues concerning science, where, in relation to its fossil fuels economy, Alberta is at times perceived as being less concerned about environmental science issues than Ontario (See McCarthy, April 9 2014). The two provinces also vary in terms of science achievement, where Alberta has a higher rate of self-described interest in new scientific discoveries, a higher percentage of residents who are scientifically literate, and higher science scores on PISA, an international examination that tests 15-year-olds for scientific literacy among other educational parameters (Council of Canadian Academies, 2014). Despite these differences, Ontario and Alberta also have shared qualities, including a documented focus on scientific literacy in public education (Alberta Education, 2014; Ontario Ministry of Education, 2007).
Five participants in total were interviewed to provide a variety of views and experiences while still being a small enough sample size to permit project completion in the short timeline of the Master of Teaching program. All participants were made aware of the topic and scope of the research project and signed a consent form outlining their role and rights prior to participation (see Appendix A). The details of sampling criteria, recruitment methods and who the participants were are elaborated upon below.

3.3.1 Sampling Criteria

Criteria to participate in this study were that teachers:

1) must be qualified to teach in their respective province as certified through the Alberta Teachers Association (ATA) or the Ontario College of Teachers (OCT),
2) have taught science to intermediate students for at least five years,
3) have undergone formal post-secondary science education such as a B.Sc. or a B.A. in science, and
4) have a self-identified commitment to teaching scientific literacy.

Criteria item one was implemented to ensure that teachers interviewed were professional educators and had worked with the science program within their own province. Criteria item two was in place to ensure a certain degree of familiarity and comfort with the science program in their province. A minimum of five years science teaching experience further ensured experience with assessment in the sciences, as well as the time to potentially have follow-up encounters with past students. The third criteria of formal post-secondary science education was implemented to select for participants with a background in science.
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and thus increased ability to speak with confidence on the subject, and have an educated, personal understanding of what it means to be scientifically literate. The final criterion further ensured that participants had an interest in teaching scientific literacy, and would be able to draw on their own teaching experiences to answer the interview questions about scientific literacy education within their own practice.

3.3.2 Sampling Procedures and Recruitment

Considering the short period for recruitment available for this study, convenience sampling was utilized to recruit participants. Strengths of convenience sampling include conservation of time and resources (Creswell, 2007). Convenience sampling is often identified as lacking rigour and diversity, and to help compensate for this an element of purposeful sampling was utilized to help provide a more diverse sample of teachers interviewed (Marshall, 1996). This involved assessing the potential participants who volunteered, and among those individuals selecting as diverse a group as possible, keeping in mind what jurisdiction the volunteers were teaching in, length of career, and type of science background.

Study participants were found through personal and extended connections that were developed through personal networks, personal educational experience, and contacts with professional organizations, specifically the Science Teachers’ Association of Ontario (STAO). Furthermore, it should be noted that as a student in the Master of Teaching program at OISE, I utilized connections of both peers and professors in my academic circle. Individuals, principals, and professional organization leaders were contacted by email as guided by the approved ethics protocol. When principals and associations were contacted,
they were provided with a brief overview of the study and the sampling criteria, and asked to pass on this information to teachers they thought might be applicable and interested. This strategy was implemented to help guarantee that all participants were indeed volunteers, and to avoid the pressures of having immediate direct contact between researcher and potential participant. The strengths and limitations of these recruitment methods are further elaborated upon below.

3.3.3 Participant Biographies

Alex is a public high school science teacher in Calgary, Alberta. Alex did a B.Sc in physics before pursuing a Bachelor of Education (B.Ed). He began his fifteen year teaching career teaching electronics, mechanics and woodshop before switching to sciences, which he has taught for the past fourteen years. He has many years’ experience teaching grade ten science, as well as grade eleven and twelve physics which is his current teaching focus. All of his teaching has occurred at the same public high school. Scientific literacy is important to Alex because he believes people need a basic understanding of the science used in the world to succeed.

Bailey is a grade seven science teacher in Calgary, Alberta. Bailey did a degree in biochemistry and microbiology, and worked as a scientist for a number of years before pursuing her B.Ed. She has been teaching for fifteen years, and began her teaching career with grade eleven and twelve chemistry and biology, and has also taught grade nine, teaching science and math as well as some social studies. She works for a catholic board, has taught in the classroom and in a resource room, but has spent most of her career teaching online.
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Scientific literacy is important to Bailey because she believes it helps people be more aware of their own thinking and supports them in making good decisions.

Casey is a public junior high science and math teacher in Calgary, Alberta. She pursued an undergraduate degree in biochemistry before completing a Master of Teaching program. Casey has been teaching for twelve years, and has taught students in grades seven through nine. Casey has primarily taught math and science but has also taught a few complementary courses in the humanities. Scientific literacy is important to Casey because she believes it gives people an increased awareness of the world and the confidence to ask questions.

Dylan is a public high school science teacher in Toronto, Ontario. Dylan completed a co-op biology degree, and worked at a number of science laboratories and scientific government organizations during and after her studies. Dylan then entered a teaching program and has been teaching in the classroom for the last seventeen years. In that time has taught science to grades nine through twelve, including senior biology and chemistry. Her teaching experience includes enriched science courses. In this time Dylan has also done her Masters of Education (M.Ed) and contributed to numerous professional development endeavors for science teachers. Scientific literacy is important to Dylan because it gives people the tools to be aware of important decisions being made, including those made by government, that have scientific relevance.

Evan is a public high school science and math teacher in Toronto, Ontario. Evan did her B.Sc and M.Sc in physiology before pursuing teaching, which she has been doing for eighteen years. Evan has taught primarily science, biology, and math to students in grades
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nine through twelve, in addition to teaching OAC (Ontario Academic Credit or “grade thirteen”) before it was phased out. For three of these years Evan taught teaching fundamentals and biology education to B.Ed students at a university. Scientific literacy is important to Evan because she believes it is an important element in how strong decisions are made, especially at the government level in regards to environment and energy.

3.4 Data Analysis

The data analysis component of qualitative research involves the strategies of data organization, coding and organizing themes, and representing the findings (Creswell, 2013). However, qualitative data analysis is not a linear process, and as such the methods described below were not conducted in a linear fashion, but rather through a “spiral” of returning to different steps as the need arose for this particular study (Creswell, 2013; Huberman & Miles, 1994).

Interviews were transcribed as described above, pseudonyms were assigned to protect the identities of the participants, and any identifying information was removed. To begin the coding process, interviews were read through multiple times individually for overall understanding, and to help develop a strong sense of each interview before the text was broken down (Agar, 1980). At this time initial interpretations and ideas were recorded for consideration in the upcoming coding stage (Taylor & Bogdan, 1984). Categories were developed by considering individual interviews and identifying subjects that were repeated throughout the transcripts and relevant to the research questions (Stuckey, 2015). This was done using an emergent method rather than drawing on a list of pre-existing categories so as to remain open to the discovery of unexpected or alternative topics (Crabtree & Miller, 1992;
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Creswell, 2013). Considering the categories, themes were identified using patterns in the emerging categories.

The interviews were examined horizontally, reconsidering the generated categories and adjusting them so as to have no more than 30 categories total to keep the analysis manageable in the timespan of this project (Creswell, 2013). Continuing horizontal analysis, codes and themes were considered, and additional themes were generated as they emerged. Altogether five primary themes were identified. Similarities and contradictions between the interviews in terms of categories and themes were noted at this time, as well as notable categories and themes that were absent from the data. In this way null data was addressed. This was done with continuous consultation with the literature to provide further grounding in the research about science education (Auerbach & Silverstein, 2003). Findings are further discussed in light of the research in Chapter Five: Discussion.

3.5 Ethical Review Procedures

The procedures of this project followed the approved ethics protocol for the Master of Teaching program at the Ontario Institute for Studies in Education at the University of Toronto. Under this ethics protocol, recruitment of participants could only be by phone, email, or in person, limiting the pool of potential participants, discussed below. No form of compensation was provided in return for participation. No known risks for participation of this study were identified.

Participants signed two copies of a consent form outlining their role in the project and rights for their participation prior to the interview; one copy was maintained for research purposes and the other was for the participants’ personal records. Participants were reminded
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prior to the start of the interview that participation was voluntary and could be withdrawn in part or in whole at any time. This included the option of not answering any given question, as well as revising or redacting statements in the final transcript. Every effort was made to ensure comfort of the participants.

Identities of the participants were fully protected by way of pseudonyms, which were applied during the transcribing stage of the data analysis process. Any information that might compromise anonymity of the teachers themselves or that of their students was also removed or altered from the responses, including specific roles, colleagues and school names.

As described above, all audio recordings and text transcripts were saved on a password protected Microsoft Surface 2 that was only accessible to my research supervisor and myself. Data were retained with the understanding they would be deleted after a project completion, to a maximum of five years.

3.6 Methodological Limitations and Strengths

The constraints of the Master of Teaching program limited the scope of this project in a number of ways. First, the timing of the project is guided by the program, which limited the time for participant recruitment, data collection and analysis to approximately six months. This limited the time available to network and recruit a variety of participants within the scope of the approved ethics protocol, potentially leading to a pool of participants with less varied views on the interview topics. This timing restraint further limited the number of participants recruited to five. While this sample size is small, it did permit a more focused
study of each participant’s responses, and fostered depth where breadth may have been lacking.

The use of interviews as the sole data collection instrument was another limitation. How the teachers in this study represented themselves in their interviews may not correspond, or only correspond in part, to their activities in the classroom (e.g. Colwell et al., 2013). Although not without challenges classroom observations provide a direct method of collecting information on teaching practices (Meyer, Cash, & Mashburn, 2011). Nevertheless, as a qualitative study investigating teacher conceptualizations and practices, I was more interested in hearing about teachers’ lived experiences than I was interested in verifying whether their actual teaching practices aligned with their beliefs.

Finally, a limitation of this study is that one of its primary questions is about a process that may be very difficult to do: assessing for development of enduring scientific literacy. This is a difficulty in two parts. First, scientific literacy is a concept with varying definitions which makes identification of an individual as “scientifically literate” difficult. The literature is scattered with varying definitions of scientific literacy, and similarly the participants of this study did not share a single definition of this key concept. Secondly, classroom educators do not consistently participate long-term follow up of their students. As a result of these challenges, teachers were inconsistent in their ability to provide descriptions of their students’ enduring scientific literacy. However, as this study sought to understand teachers’ conceptualizations and practices, the limited responses to this question brought forward a potential short-coming of Canadian education systems in the lack of clarity in educational
goals and consistency in long-term student follow up. This is discussed in more detail in Chapter Five: Discussion.

3.7 Conclusion: Brief Overview and Preview of What is Next

In summary, this project addressed the topic of practices of intermediate teachers that support the development of life-long scientific literacy. This was done by first reviewing pertinent literature, and then using semi-structured interviews with five Canadian teachers. Interviews were transcribed and analyzed for major themes brought forward by this small sample of intermediate science teachers. Next, in Chapter Four: Findings I report the research findings, and in Chapter Five: Discussion I discuss the broader implications of these findings in light of the existing research literature in this field of study.
Chapter Four: Findings

Introduction

In this chapter I will be reporting and discussing my primary findings to answer the research question “How are a small sample of Canadian intermediate teachers developing life-long scientific literacy among their students?” This data was collected from five semi-structured interviews with experienced intermediate science teachers: Alex, Bailey, Casey, Dylan and Evan, for whom descriptions can be found in Participant Biographies in Chapter Three: Research Methodology. My findings are organized into five themes: science teacher identity, teacher conceptions of scientific literacy, approaches to teaching scientific literacy, assessing scientific literacy, and scientific literacy and society. I will be discussing my findings related to each of these themes, comparing what was and was not found across interviews, and relate my findings to the literature. I will conclude with a brief discussion summarizing and connecting the themes before considering implications of these findings and related recommendations in Chapter Five: Discussion.

4.0 Science Teacher Identity

Being a science teacher was a key part of the identity of all participants interviewed. In particular all participants provided stories indicating their interest in science was cultivated while young, which is the first subtheme discussed below. Participants all described a strong connection with science as a professional scientist or a science enthusiast: subthemes two and three. These elements of the science teacher identity were integral to how the participants went on to describe their own conceptions of scientific literacy and also provide insight as to how these teachers model their own corresponding teaching practices.
4.0.1 Science Interest Developed while Young

Without exception, all participants indicated that their interest in science was developed while they were young. A few participants gave specific anecdotes they thought might have been the initial spark of their scientific interest, including Alex who met an astronaut when in grade two, and Casey who recalled an interest in dinosaurs as a child and regular trips to a paleontology museum. Other participants found that it was in school that their science interests grew, such as Bailey who was inspired by her grade eight science teacher to pursue science, and Evan who was fascinated by high school biology. Finally, Alex, Casey and Dylan all described supportive environments in which their families encouraged science interest when they were children.

There was not a single repeated narrative among participants in regards to development of personal science interest beyond the fact all participants indicated their interest in science developed prior to post-secondary education. This is interesting as not all participants provided an indication their experiences with elementary school science were positive, which Gibson & Chase (2002) describe as being the foundation of positive science attitudes. Instead some of the participants were inspired by science outside the classroom or in science classes in the later grades. While these findings support the idea that it is important to instil scientific literacy in students while they are school-aged, it throws into question if there is a certain age at which scientific interest develops and thus should be focused on.

4.0.2 Teacher as Scientist

By design all five participants had bachelor’s degrees in science. In addition to this university experience Bailey, Dylan and Evan all spent time working as scientists prior to
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beginning their teaching careers. In particular Evan spoke about how her time doing her M.Sc was fundamental to her own understanding of science and scientific literacy. Dylan made connections to her time working in science research when facilitating professional development and planning lessons, attempting to provide to her students accurate visions of what research labs look like in terms of staffing diversity. Alex also liked to utilize his background as a physics undergraduate by bringing science equipment he made while in university into the classroom for demonstrations. There were no clear differences between participants from different provinces in this matter. It is interesting to note that most of the teacher-participants grounded their understanding of classroom science with their experience as academic or professional scientists considering that scientific literacy is typically discussed in the literature as something that is for all people and not just science professionals (i.e. Alberta Education, 2014; Ontario Ministry of Education, 2007; Roberts, 2007; Roberts, 2011). However the scientific background of intermediate science teachers can be highly variable, and these findings may not reflect the views and experiences of science teachers with less scientific training. This harks to the discussions of science teacher preparation, which is usually centered on secondary school teachers rather than middle school or junior high: further understanding of the science backgrounds of intermediate science teachers may help increase understanding of how scientific literacy instruction is approached at this level.

4.0.3 Teacher as Science Enthusiast

All five participants were enthusiastic about science. Alex, Bailey, Casey and Evan all used the word “love” at some point in their interview to describe how they felt about science. Bailey regularly referred to herself as a “science geek.” Perhaps more telling was the
language that some of the participants would use when talking about some element of
science. For instance, when asked what experiences contributed to his own feeling of
scientific literacy, Alex had the following to say:

Just amazement at the world you know just ah you walk out you see a sunset or a
rainbow and you just kind of wonder what makes that happen where a wave breaks just
just kind of that wonder.

Similarly, Dylan would often spend several minutes speaking passionately about a current
issue in science before connecting it back to an interview question. This enthusiasm for
science clearly was important to the teaching practices of each participant.

Enthusiasm for science have been discussed in the literature as being a tool for
teaching (Oliveira et al., 2012) and a definition of scientific literacy itself (Council of
Ministers of Education, 1997), both of which are topics discussed further below. Enthusiasm
was clearly an element that was important to this small sample of intermediate teachers for
their own identities as scientifically literacy individuals. Enthusiasm continued to come up in
various contexts throughout the interviews, and based on the importance enthusiasm held to
these teachers in the context of scientific literacy it is worth further consideration when
researching this topic.

4.1 Teacher Conceptions of Scientific Literacy

Scientific literacy is broadly defined in the literature, and was broadly defined across
participant science teachers, and even broadly defined within a single teacher’s conceptions
and practices. Participant definitions of scientific literacy have been divided into four
subthemes: Nature of Science, Scientific Ways of Thinking, Science Content Knowledge,
and Enthusiasm. Participants also suggested other elements that could be considered facets
of scientific literacy, including basic literacy, media literacy, and information literacy, but these are not discussed here in depth in order to remain focused on the research question at hand.

The breadth of definitions provided by participants has many interesting implications, namely that it is hard to teach and assess for scientific literacy if standards for what that means are unclear. This will be further elaborated on in Chapter Five: Discussion.

4.1.1 Nature of Science

The nature of science, and education thereof, is a field of research unto itself. Akin to scientific literacy, the nature of science has a range of definitions. One commonly accepted definition comes from Lederman & Zeidler (1987) who say it refers to “the values and assumptions inherent to scientific knowledge” (p. 721), and often includes items such as the scientific method, what scientists do, and how science interacts with society and the environment (Ontario Ministry of Education, 2007). Both the Alberta and Ontario science curriculums include the nature of science as an element of scientific literacy (Alberta Education, 2014; Ontario Ministry of Education, 2007) and participants from both provinces included nature of science as an important element of their own conceptions of scientific literacy.

Bailey and Evan specifically mentioned nature of science when asked to define scientific literacy, and included methods of teaching the nature of science when describing their teaching approaches. Casey similarly included elements of nature of science in her definition of scientific literacy and her teaching practice, but did not identify it by name. Dylan was aware nature of science is often included as part of the definition of scientific
literacy and included elements of the nature of science in her teaching, but tended to refer to it as a concept separate from scientific literacy. Only Alex did not include any reference to the nature of science in his interview. Participant province did not appear to be a factor in consideration of nature of science when discussing scientific literacy.

The fact that the majority of participants included the nature of science as an important aspect of their approach to teaching is a positive reflection on the intent to nurture scientific literacy that has been encouraged by research and government for a long time (see Lederman, 1992). However, there is also a history of research exploring science teacher misconceptions of the nature of science which can be passed on to students, potentially inhibiting the associated development of scientific literacy (Carey & Strauss, 1970).

4.1.2 Scientific Ways of Thinking

All five participants included elements related to scientific ways of thinking in their own definitions of scientific literacy. While each teacher had a personalized conception of what a “scientific way of thinking” was, Evan described it in a way that connects all the elements volunteered by the participants:

And further to that um just a way you approach life with a kind of scientific way of thinking an inquiry way of thinking um about exploring and and understanding and and thinking and questioning um and I think that once we've achieved that then those students are scientifically literate.

Different participants emphasized different elements of this definition. Alex was focused on application in the sense of thinking about what was learned in class when watching the news or observing natural phenomenon, as well as using these thoughts to support opinions.
Bailey was more focused on skepticism and open-mindedness, on which she had the following to say:

For me a really a really important thing is an ability to listen to another viewpoint and (pause) consider it. You know so just a sort of that open mindedness I think that's incredibly important in science you know it it in fact it's the most important thing (laughter) in science is to be able to uh to listen to another person's viewpoint and weigh and consider it you know weigh it.

Casey was primarily focused on the idea of scientific literacy being the ability to make connections across scientific topics as well as connecting science to everyday life. Dylan identified using science thinking as important, but more so in the sense of being aware of the decisions being made, particularly at the government level, that have scientific relevance and making connections and informed opinions in those areas. Evan similarly highlighted the awareness of government decisions as a key aspect of scientific literacy whereas the participants from Alberta did not, making this one of the few ways in which the teachers from the two provinces differed noticeably in their responses.

Overall, these elements of a scientific way of thinking could be elsewise labeled as critical thinking which is “the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action” (Scriven & Paul, August 1987). It is interesting that again a primary element of scientific literacy as identified by teacher participants is a concepts that has merited extensive study as a separate concept. This will be further discussed below when examining cross-curricular integration as an approach to teaching scientific literacy.
4.1.3 Science Content Knowledge

Science content knowledge was variable in importance to the different participants. It was a fundamental element to both Alex and Casey, two participants from Alberta. Alex said certain parts of science content, such as chemical formulas, are foundational elements of scientific literacy as without them a student cannot interact with the subject matter any further. Similarly, a key element of Casey’s conception of scientific literacy was understanding vocabulary. Bailey, also from Alberta, called content knowledge the “top layer of scientific literacy.” Content knowledge is not usually the focus of scientific literacy discussions, but is clearly an element that cannot be forgotten about.

Dylan didn’t address content knowledge directly, but had some interesting views on scientific literacy that connected to it. Part of her definition of scientific literacy included the ability to extend a conversation on a scientific topic. In the process of detailing her answer she said that someone may not be able to converse about her interests, but may be scientifically literate in a different scientific field. Dylan’s definition in this area is more like Robert’s (2007; 2011) idea of scientific literacy for professional scientists which is more closely connected to the knowledge and understanding required for specific scientific fields. Evan was the only participant to not address content knowledge as an element of scientific literacy.

4.1.4 Enthusiasm

Often when talking about what scientific literacy is, or how it can be recognized, the participants talked about excitement, engagement and enthusiasm. Alex talked about recognizing scientific literacy as a “deeper interest” in science, and Bailey often brought up
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curiosity in the same context. Dylan alluded to scientific literacy as having a “true love” for the field, and Bailey often talked about recognizing the scientifically literate as being excited or interested. Again, Evan was distinct from the other participants and did not speak about enthusiasm as an element of scientific literacy. The participants’ views on enthusiasm did not appear to be affected by Province of work.

Enthusiasm is clearly an important element of scientific literacy to this cohort of intermediate science teachers, and they are not alone. Engagement in science is an important part of many science classrooms, and has been suggested to be an element of best practice when teaching intermediate students (Oliviera et al., 2012). Furthermore, enthusiasm has been positively correlated with scientific literacy in previous studies (Lin, Hong, & Huang, 2012). However, after time considering these findings I question whether it is appropriate to identify enthusiasm as a de facto element of scientific literacy itself, and would suggest it may be more fitting to view enthusiasm as an artifact or indicator of scientific literacy instead. Enthusiasm was also identified by participants as a tool for teaching scientific literacy, which is discussed further below.

4.2 Approaches to Teaching Scientific Literacy

The teachers interviewed tended to identify scientific literacy as a concept that was either taught continually throughout the year as an undercurrent, or as a concept directly addressed near the start of the year and drawn upon regularly when engaging in additional topics afterward. As such, the approaches described to teach scientific literacy were often simply reduced to any teaching approach the participants drew upon in their science classroom for a multitude of purposes. The wide range of approaches described or suggested
can be found in Table 1. Further resources that supported these teachers in their endeavor to teach scientific literacy can be found in Table 2. The bounds of this study do not permit the full discussion of each suggested approach or resource, and I will be specifically addressing only a few interesting approaches that were brought forward by participants.

**Table 1**: Teaching approaches described or suggested by teacher participants for the teaching of scientific literacy.

<table>
<thead>
<tr>
<th>Instructional Strategies</th>
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<tbody>
<tr>
<td>Inquiry</td>
<td>Cooperative Learning</td>
<td>Literacy Focus</td>
</tr>
<tr>
<td>Direct Instruction</td>
<td>Article Analysis</td>
<td>Student Focused Learning</td>
</tr>
<tr>
<td>Constructivism</td>
<td>Cross Curricular Integration</td>
<td>Showing Teacher Enthusiasm</td>
</tr>
<tr>
<td>Reflection</td>
<td>“Subtle” Scientific Literacy</td>
<td>Laboratory Experiments</td>
</tr>
<tr>
<td>Real World Connections</td>
<td>Differentiated Instruction</td>
<td>Teacher Demonstrations</td>
</tr>
</tbody>
</table>

**Table 2**: Resources identified by teacher participants as being supportive in the teaching of scientific literacy.

<table>
<thead>
<tr>
<th>Supportive Resources</th>
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<tbody>
<tr>
<td>Media Articles</td>
<td>Professional Development</td>
<td>Lab Equipment</td>
</tr>
<tr>
<td>Internet</td>
<td>iPads</td>
<td>Trade Books</td>
</tr>
<tr>
<td>Colleagues</td>
<td>Science Fair</td>
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Cross curricular integration was an explicit interest for Alex, Casey, Dylan, and Evan. Casey was very focused on basic elements of literacy, often speaking of the importance of scientific vocabulary and especially terms that have science-specific meanings (i.e. observation). Approaches similar to this can be found in the literature where help interpreting science texts is frequently required even for those students who have established basic literacy (Chall, 1996; Fang, 2006). Dylan and Evan also described literacy focuses, although they did not explicitly describe it as such, through integration of science articles.
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from popular media. Dylan used articles from the newspaper for projects and assignments, and was particularly passionate about connecting the science discussed in the classroom to topics that were in the news such as reproductive technologies. Evan used articles and political comics to encourage her students to demonstrate their understanding of the nature of science. Evan also spoke about an exciting project in which her students read about a current energy issue and wrote to their local politicians about it. This integration of journalism is recommended by Polman et al. (2014) where the participating teachers found this approach to be a positive science experience. Alex was more interested in integrating all subjects with science, not just literacy. He described how in his lectures he liked to explore the history and social connotations of the scientific concepts he was teaching. He also described a desire to see greater cross curricular connections with all subjects, on which he had the following to say:

Um I just think every subject not just science subjects but math and social studies and English need to complement each other um you know in science when I'm taking about nuclear weapons we can talk about a bit of social studies with a bit of history with that um social could say well you know it's a add some science to it um you know or even you know societies of the past the best science typically being the societies that kind of run the world for for those times right um you know become the super powers you know they have the best militaries if they have the best science you know you can kind of bring that into social studies um even in in English um and there's a poetry in science too right people don't always see…Yeah and if you can kind of discuss that in English class that's kind of neat or just or an elegance to it and bring that kind of English aspect into the science class you know like there's a way solve this formula this way or you can do it this way it's more elegant or poetic you know.

Overall, cross curricular integration was a common teaching approach used by these teachers to promote the development of scientific literacy, and is an exciting method to continue exploring.
As described previously, enthusiasm was found to be an important element of teacher identity in addition to being an aspect of scientific literacy for some of the participants. Enthusiasm was further described by Alberta participants Alex and Bailey as an important teaching tool for the teaching of scientific literacy. Both Alex and Bailey spoke of the importance of letting teacher enthusiasm be apparent when teaching science as a way of encouraging their students to be similarly excited. It has been previously noted that without enthusiasm, excitement and engagement from students it can be much more difficult to teach important concepts (Oliviera et al., 2012). Furthermore, a key goal of intermediate education is to maintain interest in science, which is positively correlated with academic success and further pursuit of science past the mandatory intermediate years (Gibson & Chase, 2002; Oliviera et al., 2012; Schiefele & Csiksentmihalyi, 1995). With this in mind, it is worth thinking about the teacher’s own attitudes about science when working to improve student attitudes about the subject; a suggested element of scientific literacy both in the literature (Alberta Education, 2014; Council of Ministers of Education, 1997) and by these participants.

Nature of science was often described by participants as difficult to teach, and an interesting idea presented by Bailey was the idea of teaching the nature of science, and therefore scientific literacy, through “subtle science teaching”. Bailey’s own experience as a student was one where she couldn’t pinpoint a moment that sparked her interest in science and corresponding feeling of scientific literacy, and as such in her own teaching aimed to create the same “really small aha moments” that she thinks may have inspired her. Further to this, Bailey thought the nature of science and scientific literacy were boring for kids, so she instead attempted to “infuse it into the background”. This idea that scientific literacy is
something that cannot be explicitly taught, or at least not explicitly taught in an engaging way, is one that could be a road block in both the research and teaching of scientific literacy, and merits further attention.

An important takeaway from these findings is that there is not one single way that teachers are trying to teach scientific literacy. There was also no clear tendency for teachers from one province to rely more on any given approach. The literature is full of various approaches, and over time different ministries of education, school boards, and individual schools have each encouraged one form of instruction over another. Casey had this to say on the topic:

I find that sometimes you know we are be some sometimes you're being sort of encouraged only in like one way to teach and not you know like … I feel like every few years you know there's like there's a push for okay well stop teaching the traditional way and we should only be doing inquiry based learning and and I weh and that not something I necessarily agree with like I think inquiry based learning is b really big important part of of teaching especially teaching science but I don't think it's the only way I I think just having you know being basically being more encouraged uh just to be more balanced in our our teaching approaches rather than um pre being pushed in certain ways because of you know new research or new the literacy [literature] that comes showing this or that you know what I mean?

While it is important to investigate which methods are successful in the education of our students, it is also important to remember that shifts in promoted instructional strategies be met with great opposition (i.e. Kilpatrick, 1997), and that there is a lot of room in teaching in the Canadian context to implement strategies based on professional judgement.

4.3 Assessing Scientific Literacy

An important aspect of teaching is assessment, or the collection of data to tell if a student is achieving the set expectations (Ontario Ministry of Education, 2010). However,
multiple participants struggled with how to assess scientific literacy. For instance while Dylan was passionate about scientific literacy education, especially in terms of social awareness, she was unsure of how she could begin assessing her students for scientific literacy. When asked how she assesses her students for scientific literacy, she said:

Um I don't know if uh I don't think I do I don't know how I can and I have thought about that a lot actually because I think especially with like environmental attitudes that have a lot of strong opinions on some of that and I try to remember where I got it from… so how to assess them I don't I don't know how I would and I don't know where my own attitudes came

This may indicate a serious underlying problem in education for scientific literacy: what are teachers supposed to assess for? Considering the breadth of the definitions of scientific literacy it is unsurprising that this is an issue. Furthermore, Dylan’s statement presents an interesting idea: is scientific literacy related to attitudes, or to how they were formed? Casey, Bailey and Alex all also used attitudes towards science, namely enthusiasm and engagement, as evidence of scientific literacy development in their students. However, enthusiasm for science is not the necessarily indicative of scientific literacy: in the Council of Canadian Academies (2014) report on science culture it was found that while over 90% of Canadians were interested in new scientific discoveries, only 42% were found to be scientifically literate by the study’s parameters. Clearly attitudes and actions based on them are not direct measurements of scientific understanding and thus may be a poor tool for assessment of this literacy.

When participants had a direct answer for how they assess scientific literacy development their methods tended to rely on professional judgement. Both Bailey and Evan used traditional means of assessment such as short or long answer tests, and from those
would interpret whether their students were exhibiting scientific literacy. While they were confident in their assessments, they were not able to give specific examples or easily measurable traits they looked for when assessing. For instance, Bailey described her students’ assessed work as follows:

I can’t think of an [unintelligible] specific example but you can see a student on a test who ha how do I tell if they really really get a concept ih ih it's it's actually it's it's different it's it's in some ways it's they’re ability to really explain in depth you know you can tell they're not just copying out of a textbook or they're haven't just memorized what they're supposed to say you can tell they really can visualize what's happening

This “you can tell” narrative was one that was common across participants, and while the participants who used this strategy appeared to be confident in these assessments, they are difficult to evaluate without further examination of the work being assessed. This poses an additional difficulty in understanding the best practices for assessment in the development of scientific literacy.

Finally, the participants did not have a strong sense of the long-term maintenance of scientific literacy in their students. Casey and Dylan both had occasions in which they taught students two years in a row, but did not comment on these students’ continued scientific literacy development. Evan had an instance in which she taught a class of students with learning disabilities and the next year received positive feedback from the class’ new teacher who thought the class was well prepared in terms of knowing some of the key nature of science vocabulary and inquiry skills. Such a follow-up was an opportunity for Evan to affirm her choice of teaching approaches but is not a kind of feedback she received at other times. Some of the participants had prior students visit them, but found that these conversations were often superficial or only identified if the student was still enrolled in
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science, which most participants suggested was not necessarily indicative of scientific literacy as there are a multitude of reasons students may pursue science classes after it is a graduation requirement. However Alex had a unique experience among the participants in that he was able to speak to what he deemed to be a continuation of scientific literacy by his running into former students at science cafes and centers:

I run into former students there and just “hey I wanna” you know and they graduated a couple years ago but they just like hanging out to do that stuff so that's really interesting that that they're still interested in the science even though maybe their career hasn't gone that way… I don't know what the other girl was doing but yeah sh you know she went down there just to just to look at stars one night right so I think that's showing some scientific literacy or just a curiosity about it…

Such actions demonstrate an additional level of valuing science by taking time to explore it years after mandatory education, and if attitudes and interest in science are included as a definition of scientific literacy then these encounters could be used to affirm Alex’s teaching approaches. However Alex was the only participant who was able to speak to enduring scientific literacy in this way, highlighting an information gap in teachers’ abilities to assess long-term scientific literacy development and attainment.

Overall assessment is clearly an issue in the instruction of scientific literacy. The participants here provided wide ranges of definitions of scientific literacy which did not always align with what they were trying to assess. This was found for participants from both provinces questioned. Many of the teachers interviewed identified assessing scientific literacy as difficult or even said they did not attempt to do so. Finally, there was very little long-term follow up with students by which the teachers could evaluate their own teaching approaches. Clearly, assessment in scientific literacy needs more attention, as the assessment
methods used by large organizations such as OECD (PISA) or the Canadian Government are further different in what they evaluate compare to what is focused on in schools and used by teachers (Council of Canadian Academies, 2014; Government of Canada, 2013).

4.4 Scientific Literacy and Society

While pursuing this research study some issues came to my attention that may be further hindering the advancement of scientific literacy as a whole. As mentioned above there may be flaw in equating interest and enthusiasm in science with scientific literacy. Even though attitudes in science are an element of some definitions of scientific literacy (Alberta Education, 2014; Council of Ministers of Education, 1997), most studies that have examined attitudes towards science have found that enthusiasm is positively correlated with scientific literacy and not a causal effect (Lin et al., 2012). Too concentrated a focus on enthusiasm and enjoyment could lead to issues where students are not learning any better, but rather where they come to expect that all science should be exciting and presented as such (Postman, 1985). If this is the case there could be future issues where adults are disengaged with science when it is not packaged in an entertaining way, as is often found in government or academic communications. It is the belief of this researcher that it could be short-sighted to think enthusiasm for a subject is the same as understanding it, and I believe that more stringent measurements than enthusiasm should be used when assessing scientific literacy.

Another concern that arose was the state the culture of science in Canada. The participants tended to justify scientific literacy as something students need even if they are not going to pursue science as a career, while simultaneously providing anecdotes of students who pursued science in their post-secondary education as scientific literacy success stories.
This may indicate that how our culture values science is not aligned with the curriculum intentions of scientific literacy: it is possible that people still think of science as something for scientists. Further to that some communities are opposed to science as Bailey mentioned when talking about the religious radicalism she sometimes experienced from parents. Curriculum has frequently been identified as a cultural endeavor (Caswell, 1943; Nakpodia, 2010), but what remains to be seen is if our curriculum will lead our culture, or ultimately change to align with it.

Finally, an issue that was not especially apparent in the interviews done here but is something I have regularly observed as I have immersed myself in the education community is society’s conception of science as a black and white topic. Casey often talked about some of her students being more passionate about humanities and language, and others being more drawn to math and sciences. This is a divide that I experienced in my own education and continue to observe in students today. This could be an additional roadblock in developing scientific literacy in Canadian students and by extension Canada: students might think that if they like one subject they automatically are distanced from another. Furthermore, this corresponding view of science and math being fact-based, and humanities, languages and arts being expressive is a dangerous misconception for all subjects concerned. In my personal experience this view fosters hostility towards science when contradicting findings come out. This topic is one of interest to many researchers (e.g. Arapaki & Koliopoulos, 2011; Asher & Director, December 2007), and may be worth further exploring to the betterment of the scientific literacy of Canadians.
4.5 Conclusion

In this chapter I described my primarily findings about the practices of intermediate teachers in the development of life-long scientific literacy. I found that the teacher participants of this study founded their scientific literacy in their experience while school-aged and often also while working in science professionally, and that a personal love of science was integral to many of these teachers’ relationship with the subject. The participants brought forward a range of definitions of scientific literacy, including the nature of science, scientific ways of thinking, science content knowledge and enthusiasm for science. Further to this, the participants had a wide range of approaches they used to teach scientific literacy and were supported by a large number of resources. However, linked to the wide range of definitions of scientific literacy, these participants often struggled with assessing scientific literacy or were unable to describe in detail what they assess specifically, often relying on the hard-to-describe professional judgement. Overall there was little noticeable differences in the above findings between the teachers from Alberta and Ontario, with the exception of the two teachers from Ontario having a greater focus on scientific literacy being important to understand government decisions. Finally, I described some of my additional concerns with scientific literacy education that may be linked to Canadian science culture as a whole, such as black and white views of science and a prevalent idea that science is only for scientists.

Altogether, these themes come back to the unclear definition of what scientific literacy is. If we don’t know what it is, how can we know how to develop it? While there are similarities in these teacher’s personal experiences of developing scientific literacy, they are...
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not experiences that could be easily replicated in a middle school classroom: even the participants that connected their schooling to their passion in science were often unable to identify what it was about their own education that fostered their own scientific literacy. From this, it is unsurprising that teaching approaches and assessment practices vary widely, and that teachers are uncertain of their own success in teaching for scientific literacy. Compounding all of this is a potentially harmful cultural conception of science, in which scientific literacy is not thought of as something for all, but rather only for those who are scientists.

Considering the literature, these findings are a little surprising and may indicate a disconnect between research and classroom practice. There are many studies which acknowledge upfront that scientific literacy is widely defined, but they have a tendency to move on or choose a single definition for the purpose of their research (i.e. Phillips & Norris, 2003). As a result, studies are often making statements about the state of scientific literacy education that are missing a huge component of how teachers are conceptualising their own classroom. This is a fundamental issue in science education and it throws into question the value of large scale assessments such as PISA or the Council of Canadian Academies’ Science Culture Report (Council of Canadian Academies, 2014).

Clearly, scientific literacy education is an important topic of research to ensure that that the goals of curriculum are being met. The findings of this study will be further discussed in Chapter Five: Discussion, in which I will review the findings and discuss their broad implications for educational research community, as well as how they will influence my
personal research and teaching practices moving forward. I will conclude with recommendations for future work.
Chapter Five: Discussion

5.0 Introduction

In this study I began by examining the state of low scientific literacy among Canadians and asked the question: How are a small sample of Canadian intermediate teachers developing life-long scientific literacy among their students? I explored the relevant literature regarding definitions of scientific literacy and related literacies, the significance of the intermediate age group when investigating scientific literacy, as well as a selection of teaching approaches that have previously been highlighted in the context of teaching for scientific literacy. Collecting and analyzing data from semi-structured interviews with five intermediate science teachers, I found this small sample of teachers used a variety of approaches when trying to teach for enduring scientific literacy, but were inconsistent in their definitions of what scientific literacy is and further struggled with how to appropriately assess this complex topic. In this chapter I will provide a brief overview of the findings described in Chapter Four: Findings before exploring some implications of these findings on both a broad and narrow scope. I will then provide some recommendations for future practice of teaching for scientific literacy as well as suggestions for directions of future educational research.

5.1 Overview of Findings

Understanding teaching practices in relation to scientific literacy instruction was complicated by the vast range of definitions provided for this key term. Each participant not only defined scientific literacy differently but also had variation in how they defined the term
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depending on the context of the interview question. This highlights an issue in the
instruction of scientific literacy, as it is difficult to say what Canadian education systems are
trying to instil in students to support them in scientifically relevant situations they encounter
in adulthood.

Differences in the science backgrounds of the participants may have contributed to the
range of definitions for scientific literacy found in this study. The participants had a wide
range of scientific experiences, and while all participants had formal university educations in
science, some participants had experiences in higher levels of science academia or in the
workplace, and some identified as science enthusiasts. The wide range of science
backgrounds amongst all intermediate science teachers is even broader when we consider
that fact that science classes at the intermediate level do not always have subject-specific
teachers. If science background influences how science teachers define and teach scientific
literacy this is an element of scientific literacy instruction that may merit further
investigation.

Each of the teachers interviewed provided a different set of approaches for the
instruction of scientific literacy, suggesting that there is no single way that intermediate
teachers develop life-long scientific literacy in their students. Some prominent instructional
strategies implemented by these teachers included inquiry, making real-world connections,
and being enthusiastic, and “subtle” scientific literacy, which is the weaving an undercurrent
of scientific literacy and nature of science into other elements of the science class. This wide
range of approaches and practices may have been linked to the range of definitions provided
for scientific literacy. Teachers further mentioned many helpful resources that supported
them in the instruction of scientific literacy, notably colleague support, online resources, and access to laboratory equipment. Key factors that participants found challenging when teaching scientific literacy included time limitations and curriculum both in terms of volume and content choice.

Assessment was identified as a further impediment to the successful instruction of scientific literacy. Participants struggled with how to assess scientific literacy to the point that some said that they were unable to. Some participants were more confident and stated that they did assess for scientific literacy, but were able to give clear justifications for their assessments and relied primarily on professional judgement. As assessment is an important factor for the improvement of student learning this is a troubling finding and will require further attention to ensure that we are monitoring the development of scientific literacy in our students.

5.2 Implications

The findings from this study have a number implications both for the broader educational community and for my own professional identity and practice. These are discussed below.

5.2.1 Broad: The Educational Community

The primary finding of this study was that scientific literacy is broadly defined both in the literature and across and within teacher practice. This is troubling for the future of scientific literacy instruction as it is difficult to say if scientific literacy is being learned if what the term means is unclear. Some teachers may be unsure in their own practice about what their goals for teaching scientific literacy should be, and the goals set by teachers and
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schools may be discordant with the goals of governments and ministries of education. This could also be causing issues in educational research where most studies begin by choosing a working definition of scientific literacy that may not be the same as that used by the teacher-participants. This has been seen in other areas of educational research, where teachers interpret pedagogical terms in ways that do not align with that of the researcher, which leads to negative findings rather than insights on teacher perceptions (i.e. Colwell et al., 2013). Overall, this lack of clarity for what teachers should be working for in scientific literacy education is detrimental for students who may be receiving inconsistent instruction and possibly experiencing lower scientific literacy outcomes.

The challenges my participants had in assessing the development of scientific literacy have further implications for the educational community. Assessment is meant to improve student learning, and if teachers are struggling to assess development of scientific literacy, or not assessing at all, students are once again at a risk of having poorer scientific literacy outcomes (Ontario Ministry of Education, 2010). Teachers, students, and parents may be in a situation where they do not know how students are progressing in the development of this important literacy. Teachers in particular may be frustrated about how to proceed with their science instruction or possibly even abandon it. Even when teachers do feel confident with assessing scientific literacy if it is by means of professional judgement teachers may struggle to communicate these assessments to students and parents with sufficient evidence. Finally the validity and utility of broader scientific literacy assessments may be in question if teachers are unable to assess scientific literacy within the confines of their classrooms. Teachers may not be able to integrate results of such tests to improve student learning if their definitions of scientific literacy are different from that used by large scale assessments such
as PISA, and may be limited in their ability to improve science scores on such tests if their own assessment methods are flawed or absent.

The wide array of teaching practices found and explored in this study have promising implications for the educational community. Students may be well-served by the variety of teaching approaches used, and have opportunities to develop scientific literacy by the range of learning experiences these approaches provide. If the approaches described above are good strategies for scientific literacy instruction this also means that teachers have a wide arsenal of tools to draw from when teaching this topic. The approaches described in this study were higher in number than what is prominently featured in the literature through the scope of my research, which could also mean that educational researchers are missing effective methods for scientific literacy instruction through focusing on a few select approaches.

Finally, the development of scientific literacy may be limited as a result of some key hindrances described by the participants of this study. The intermediate science teachers in this study highlighted issues they had with time limitations and curriculum overloading. As it stands, the time allotted for science instruction and the volume of curriculum to cover may mean that teachers are struggling to find the time teach scientific literacy effectively, which means students may not be developing this literacy and further contributing to the problem of low levels of scientific literacy in Canada (Council of Canadian Academies, 2014).

5.2.2 Narrow: Professional Identity and Practice

In terms of professional identity and practice the findings of this study have reaffirmed my belief that scientific literacy is a topic that will require specific attention in my future
classroom. The participants in this study provided numerous examples of how scientific literacy is an important element of informed citizenship, and I continue to believe that establishing this literacy in my students should be a priority. Furthermore, the ranges of scientific literacy definitions provided, and descriptions of challenges in assessing scientific literacy, highlighted the need for me to be purposeful in my approach to teaching scientific literacy. As a result of these learnings I will consult with the curriculum to establish a definition of scientific literacy to support my practice and ensure I am consistent, and so I can share with my students what they are working towards. Coupled with this I will be mindful of assessment when teaching for scientific literacy, and establish from the beginning what success criteria and learning goals I have, and from this be better equipped to assess both my students and my own practice.

Another element that came forward in this research that will influence my professional practice is the understanding that perceptions of science influence science education. As a student I was drawn to science in part due to the “one right answer” that I knew I could provide for questions on assignments and tests. This view of science as being a field of absolutes is held by many people I have spoken with, but I have come to think of this attitude as harmful for the development of scientific literacy. In response to this understanding, I will move forward in science education trying to highlight interpretation and discussion that is integral to science and associated progress, and try to increase scientific literacy by breaking down this misconception of science.

My identity as a researcher has also been influenced by the process of conducting this study. I began this research project as a quantitative researcher and have had many struggles
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with how to integrate qualitative research into my researcher-identity. This research experience has helped increase my appreciation for qualitative research, especially for the stories and statements it can highlight that would easily get lost in a quantitative study. However, the process of conducting this study has also had its difficulties, and in future research endeavors I would be certain to spend more time in the early stages of research understanding the problems I am trying to address and what questions are important to ask, as well as honing the data collection process to ensure that questions I have are likely to elicit the sought-out information.

5.3 Recommendations

The variations in definitions of scientific literacy is something that needs to be addressed by the education community. I suggest that all educators consider what scientific literacy means to them individually and in the context of their educational environment, and establish a clear definition of what they are striving for prior to commencing teaching for scientific literacy. This may also help improve assessment of scientific literacy as it will be clearer what educators should be looking for, and provide context to plan scientific literacy instruction with assessment in mind. Furthermore I recommend that governments and school boards publish their definitions to provide their educators with more support when teaching for scientific literacy. While there are many elements of scientific literacy that should be considered when establishing a definition, I strongly recommend that elements of the nature of science and critical thinking are included, and that the wording of such a definition be accessible to people that do not have a background in science. Establishing definitions of scientific literacy will also help initial teacher education programs prepare teacher candidates
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to teach scientific literacy as these definitions can be a backbone for science teacher preparation courses. This would then also provide an opportunity to address assessing scientific literacy, an element I recommend be included in initial teacher education syllabi and extend beyond professional judgement.

Most of the teacher participants of this study cited either curriculum overloading or time limitations as a hindrance when trying to teach for scientific literacy. To address this I further recommend that governments and ministries of education revisit their science curricula to consider what is feasible to cover in a single course. Furthermore, greater integration of elements of the nature of science and critical thinking, two key elements of scientific literacy as identified in this study, should be infused in the specific expectations for science curricula.

Finally, I recommend that teachers implement more cross-curricular work to break down the barriers that can be felt between science and the humanities. Many students and teachers, including participants of this study, think of people as being science-and-math people, or language-and-humanities people, and this divide may be contributing to harmful misconceptions of all school subjects. Science has a lot of room for interpretation that is often overlooked in the classroom, but could be brought forward through the integration of language, social studies, and the arts. To help with this implementation I recommend that school administration include planning time to connect teachers from different subjects in rotary schools, and that governments and ministries of education explore policy and resource development for cross-curricular activities.
5.4 Areas for Further Research

Considering the findings of this study, an important area for further research is to investigate teacher definitions of scientific literacy. Many studies address the fact that there are multiple definitions of scientific literacy, but tend to leave the conversation there or pick one definition that works for the purposed on their study. In the scope of my research I have not found any studies confronting the varied definitions of scientific literacy present in the literature and amongst individual teachers, and how to consider and consolidate these to a working definition to use for educational purposes. Investigating this will help educators better understand how teacher perceptions of scientific literacy influence scientific literacy instruction, as well as explore the possible achievement differences found when different definitions are used. Furthermore, regardless of the specific approach to researching scientific literacy being used, a clear definition of scientific literacy as it is being used in each study must be provided to be clear on what element of this diverse topic is being investigated.

Integrating more quantitative approaches would be fitting for further research into scientific literacy instruction. Science teachers, particularly those with science backgrounds, may be more compelled to implement findings that are backed by the scientific method. As Bailey, a participant of this study, stated: “[science] is the only way to get to truth!” By utilizing quantitative approaches, researchers can measure how scientific achievement changes with different scientific literacy definitions and teaching approaches, and provide more compelling evidence to teachers when encouraging them to alter their practice.
Finally, I recommend the design and implementation of a longitudinal study about development and endurance of scientific literacy in students. The participants of this study were often disconnected with their students after the school year was over, and struggled to speak to how scientific literacy in students endured after a year under their instruction. Even when participants did have contact with their past students their relationships tended to only be with students who had a particular interest in science, and often the follow-up conversations were superficial. A longitudinal study investigating development of scientific literacy throughout primary and secondary school, as well as scientific literacy levels post-graduation, may provide insight as to what instructional approaches are effective for long term scientific literacy development and maintenance, an area that individual teachers lack the resources to do on their own.

5.5 Concluding Comments

I became concerned about scientific literacy while pursuing my Masters in Science, where it became clear to me that many people I interacted with found science to be inaccessible to them. This led me to be concerned for the state of scientific literacy amongst Canadian citizens. Fewer than half of Canadians were identified as scientifically literate in a recent survey (Council of Canadian Academies, 2014). Science plays an important role in many daily decisions, and scientific illiteracy threatens Canada’s position as a global leader in science and technology (Berry, n.d.; Council of Canadian Academies, 2014). In response to these concerns about the low levels of scientific literacy in Canada I asked what intermediate science teachers are doing in their classrooms to encourage the development of enduring scientific literacy in their students. Through semi-structured interviews with five
intermediate science teachers I found that intermediate science teachers use a wide range of approaches to teach scientific literacy, including implementing inquiry, making real-world connections to classroom science, and subtly teaching scientific literacy concepts such as the nature of science. Despite this exciting range of approaches and strategies, teaching for scientific literacy is hindered by a diversity of definitions of scientific literacy that make the goal of teaching scientific literacy unclear, as well as further difficulties such as challenges in how to assess the development of scientific literacy.

These findings are important because they give greater insight into what is happening in Canadian intermediate classrooms and provide direction for the educational community to go to improve the state of Canadian scientific literacy. In particular teachers can use these insights to evaluate their own teaching practices and make more informed decisions when planning scientific literacy instruction. Furthermore, in light of these findings governments and ministries of education can consider their science education policies and potentially adjust them to provide more clarity in their science mandates and greater support for schools, teachers and therefore also students. Educational researchers can also use these findings as a platform to further explore how teachers define scientific literacy and what an effective definition of this term may be for the purposes of intermediate education. The launching of both additional quantitative and longitudinal studies may further benefit scientific literacy teaching practices.

This study has affirmed my belief that science and scientific literacy are important. However I am still concerned that science education is not supporting our students in developing scientific literacy to support their future needs. This is in part because teachers’
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varying definition of scientific literacy could mean that students are receiving inconsistent educations, and also because teachers are struggling to assess scientific literacy development which makes it hard for teachers to know if their approaches are supporting scientific literacy development. As a scientist I felt that my education had not prepared me for the world of science, and I have interacted with many individuals who feel ill-prepared to interact with the science that is relevant to their every-day decisions. Scientific literacy outcomes in Canada need to be improved, and with consideration of these findings teachers, students, schools and governments can work together to make that happen.
References


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Appendices

Appendix A – Consent Form

Date: ___________________

Dear ________________

I am a graduate student at OISE, University of Toronto, and am currently enrolled as a Master of Teaching candidate. I am studying scientific literacy, and what intermediate teachers are doing to encourage the development of life-long scientific literacy in their students. It is my hope that studying this topic will both increase overall understanding of the teaching of scientific literacy, as well as inform my own practices as a future science teacher. I am interested in interviewing intermediate science teachers with an academic background in the sciences and a commitment to teaching scientific literacy in their classrooms. I think that your knowledge and experience will provide insights into this topic.

I am writing a report on this study as a requirement of the Master of Teaching Program. My course instructor and research supervisor who is providing support for the process this year is Dr. Angela MacDonald-Vemic. The purpose of this requirement is to allow us to become familiar with a variety of ways to do research. Your participation will entail one 45 minute interview which will be audio-recorded on my tablet. I would be grateful if you would allow me to interview you at a place and time convenient to you.

The contents of this interview will be used for my research project, which will include a final paper, as well as informal presentations to my classmates and 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, and you will be referred to by a pseudonym. Your personal information remains confidential. The only people who will have access to the audio recording and transcript work will be my research supervisor/course instructor. You are free to change your mind about participating 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 and transcript after the paper has been presented and/or published which may take up to five years after the data has been collected. Participation in this study is an opportunity to share your lived experience and inform professional development in the area of scientific literacy. There are no known risks to you for assisting in the project, and I will share with you a copy of the transcript to ensure accuracy.
Please sign below you agree to be interviewed. The second copy is for your records. Thank you very much for your help.

Yours sincerely,

Kathryn Lipsett                                      Dr. Angela MacDonald-Vemic
XXX-XXX-XXXX                                          XXX-XXX-XXXX
kathryn.lipsett@mail.utoronto.ca                     angela.macdonald@utoronto.ca

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 at any time without penalty.

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

Signature: ______________________________________

Name (printed): ___________________________________

Date: ______________________
Appendix B – Interview Protocol

Thank you for agreeing to participate in this interview today.

This interview is for my Master of Teaching Research Project which is on the topic of practices of intermediate teachers in the development of life-long scientific literacy in students. I am interested in learning how teachers conceptualize scientific literacy, how they endeavor to teach it, and what they do to encourage endurance of student scientific literacy beyond the classroom and into adult life.

This interview is broken into 5 sections: participant background, beliefs and values, teaching practices, influencing factors and next steps. At this point, I would like to remind you that your participation is voluntary, and you may choose to decline to answer any question. Furthermore, you will be sent a copy of the interview transcript, and you may choose to alter or withdraw answers at that time if you wish. Your answers will not be evaluated, and your anonymity and that of your students, including name and location, will be kept confidential with no identifying factors included in the publication.

This interview will be audio recorded using my tablet, as was indicated in the consent form you have signed. If you would like the audio recording to be terminated at any time, please do not hesitate to say do. Do you have any questions before we start?

Background

1. How long have you been teaching?
2. What grades and subjects have you taught? Where have you taught?
3. What is your background in science as a field?
4. How did you become interested in science?
5. What factors and/or experiences contributed to the development of your own scientific literacy?
6. Do you have any personal experience with research in science or science education? If yes, could you briefly describe it?

Beliefs and Values

7. How do you define scientific literacy? What does scientific literacy mean to you? What does it mean to be scientifically literate?
8. How would you recognize scientific literacy in people? What indicators would you look for?
9. Would you say these indicators are common among members of Canadian society? Why or why not? What gives you this impression?
10. Moving more into the realm of education, what do you think are the benefits of having students who are scientifically literate? Why is scientific literacy important?

Teacher Practices

11. How would you describe your approach to teaching science, generally?

12. More specifically, what range of instructional approaches do you use? What kinds of opportunities for learning do you create to develop scientific literacy in your intermediate students? [Prompt if needed: for example, do you use inquiry, hands-on experiences, or community partnerships?]

13. What are your learning goals when you teach for scientific literacy? Which particular elements of your science lessons do you hope are carried with your students beyond the classroom as enduring understandings?

14. Can you give me an example of a lesson that you have taught to enact these learning goals or enduring understandings?

15. How do your students respond to the teaching practices you have described? How do you find your science teaching practices influence the development of enduring scientific literacy in your students?

16. How do you assess the development of scientific literacy in your students? What indicators of learning do you look for? What indicators of learning have you observed?

17. Do you have any sense of the extent that student’s development of scientific literacy endures beyond your teaching? How? Why? Do you ever follow up with students you have previously taught? If yes, how do you perceive their continuing scientific literacy?

Influencing Factors

18. What resources are available to support you in your teaching of scientific literacy? [Prompt if necessary: Do you use professional development activities, designated learning spaces, allocated funds, specialized equipment, community connections, or any other resources?]

19. What factors limit your ability to teach scientific literacy in the classroom? What challenges of you confront while doing this work? How do you respond to these challenges?

Next Steps

20. In your view, what needs to be done to further support for the development and maintenance of scientific literacy in students in and out of school?

21. What advice would you give to beginning teachers hoping to foster life-long scientific literacy in their students?

Thank you very much for your time today. Before I go, I want to remind you that your participation in this study is voluntary, and if you should decide at any time during the research period you would like to withdraw your participation you can do so. Your name
and any identifying information will be removed from the transcript, and your anonymity will be maintained in the coming publication.

Thank you once again for your participation. I greatly appreciate it.