SECONDARY SCIENCE TEACHERS' UNDERSTANDINGS OF SCIENTIFIC LITERACY

by

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Abstract

Scientific literacy is an important goal of science education but one that has been difficult to define. The definition of scientific literacy has changed over its 60-year history in response to changing societal needs. These definitions have ranged from basic levels of scientific understanding to that of a seasoned scientist. In the field of education the definition has remained broad, capturing conceptual, skill based, and attitudinal dimensions. Despite being the goal of science education, limited research has been conducted into science teachers' understandings of scientific literacy. The purpose of this research was to identify high school science teachers' understandings of scientific literacy and identify perceived barriers to implementation. High school science teachers participated in a semi-structured interview to identify their views/definitions of scientific literacy and identify any barriers they face in developing scientific literacy in their classroom.

The teachers' understandings fell into three major categories: knowledge, skills and processes, and attitudes. Most teachers emphasized one category but all included all three understandings in their definitions. Teachers identified a number of ways they work to build scientific literacy and some of the challenges they faced. Barriers to successful development of scientific literacy included curricular challenges; challenges related to the student, such as motivation; and challenges related to the teacher, such as time. While teachers had varied understandings of scientific literacy, the overall understanding was similar. Further, all saw it as an important goal of science education and something they worked to develop in their students.

Preface

This thesis is an original work by Leslie Heinsen. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, Project Name "TEACHERS' DEFINITIONS OF SCIENTIFIC LITERACY IN ALBERTA", No. 43050, May 28, 2014.

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Chapter 1

Introduction

> The modern world is an outcome of science but people don't appreciate it; don't question where new technology and discoveries come from. It is amazingly unappreciated. Science needs to be seen as a part of humankind's essence; it is who we are. We are able to learn about the universe and we are able to use that learning to improve our society. (Turok, 2012)

Turok (2012) suggests that through science we can improve our society, understand how the world works, and that science has a useful, yet undervalued purpose. Ziman (2000) echoes this thought by reminding us that science is everywhere, permeating a variety of aspects of our daily lives. But why are science and scientific understanding important? When one considers the pace of scientific advancement over the last 100 years, from the structure of the atom to designer genes, the role of science has been and continues to be significant. It has been suggested by some that the public lacks the required level of scientific understanding to participate in the politics and decision making surrounding scientific issues (Bauer, 2009). These differences in our levels of understanding have allowed pseudoscientific and anti-science sentiments to thrive and a crisis of confidence to develop regarding scientific knowledge (Ziman, 2000, Sturgis & Allum, 2004). Ziman (2000) suggests these differences have created a divide between members of the public, with those who are well informed making very different decisions than those who are less informed. If the public is to participate in the debate regarding scientific topics and hold the government accountable regarding public policy, citizens need to have a certain level of accurate information (Sturgis & Allum, 2004). It is these needs that make science understanding an essential part of daily life where teachers and science education can play an important role. Scientific literacy should be a lifelong goal with the foundations of it laid by teachers during school so individuals can continue to develop beyond school and throughout their life (Koballa, Kemp, & Evans, 1997).

Science and Education

In 1910, John Dewey described the gap in understanding between scientist specialist and the general public, between the lack of students exploring the field of science and the difficulties teachers experienced in handling the volume of scientific information available for study. This declaration began the drive to make science a more significant part of science education. DeBoer (2000) wrote that early science education in schools began in the late 1800s. The humanities were strong disciplines at the time, so when considering how to approach science education it was meant to be taught as practical knowledge in a world that was starting to emerge technologically, while still focusing on the natural world. As society moved into the Sputnik and post-Sputnik era, science education continued to play a significant role in keeping students' understanding of science competitive with other nations. Since the 1980s, science education has been focused on producing an informed and scientifically literate citizenry with a strong understanding of science and technology (DeBoer, 2000). Much of this focus comes from advocates for science, technology, society and environment (STSE) education, and more recently science, technology, math, and engineering (STEM) education. Pedretti and Nazir (2011) give a complete history of STSE education and trends. Locally, in Alberta, curriculum changes are being made in all disciplines that are designed to promote critical thinking, problem-solving, collaboration, and communication to provide students with the skills and aptitudes required for the 21st century. Overwhelmingly, the goal of science and science education is to meet the needs of society at that particular time.

Hurd (1998) states that the nature of scientific literacy is evolving to reflect a changing society in areas of biotechnology, environment, communication, and energy, yet curriculum has not kept up with these changes. Most school curricula still focus on "laws, theories and concepts" (p. 41) instead of a curriculum that gives individuals the tools to cope with a changing world. While Hurd's reference was from almost 20 years ago, a glance at current science curricula in Alberta indicated the focus is trapped in the past. The Inspiring Education document, produced by Alberta Education (2010), reflects the type of educational changes needed to keep pace with societal changes and creates a framework to approach this challenge. The new framework, which has not been formally enacted in the science program of studies, includes a focus on engaged thinking, ethical citizenship, and entrepreneurial spirit. Changes in this curricula will require a shift in thinking and an approach that favors inquiry-based teaching strategies and 21st-century thinking. Anderson (2002) writes that teachers experience barriers and dilemmas when new teaching practices are enacted, and Krajcik and Sutherland (2010) indicate teachers will require changes in their instructional practices to meet these changing instructional needs. A second challenge area relates not to curricula, but rather barriers associated with developing the scientific literacy component of the curriculum. These barriers may exist in a variety of areas such as student language barriers (Wellington & Osborne, 2001), differences in economic circumstances of students' families (Fensham, 2002), or logistics such as teaching class size, time, material availability, or physical space (Songer, Lee, & Kam, 2002). Challenges with curriculum and other outside factors must be considered when discussing the development of scientific literacy.

As teachers, it is our hope that students will leave our classes inspired and eager to learn more. In addition, the goals of science education are to develop the language and problem-solving skills students need to be capable in science. That is, students need to develop conceptual understanding and be able to understand and evaluate the world around them (Duschl, Schweingruber, & Shouse, 2007). Students should be able to question and appreciate the scientific world. Further, science education should contribute to the development of productive citizens that can make informed decisions and contribute to the economies of the place where they live. These goals of science education fall under the broad educational goal of scientific literacy, and as such scientific literacy becomes a goal of science education. It is teachers that are charged with the task of helping to develop scientific literacy in their students. In Alberta, scientific literacy is the goal of the secondary science program of studies with "the vision that all students have the opportunity to develop scientific literacy" (Alberta Education, 2014, p. 1). This statement is broad and covers many objectives outlined as the goals of science education, including knowledge, skills, and attitude outcomes that would have students become problem solvers and lifelong learners.

Personal Perspective

My understanding of scientific literacy has evolved over the course of my graduate studies. Before beginning my graduate studies, I considered my students' experiences—their daily bombardment with scientific information and their need to interpret information critically to define scientific literacy. And while standardized testing ranks Alberta students as some of the best in the world regarding measured scientific literacy, my experience as a teacher, as well as anecdotal evidence from colleagues at the University, indicated that students are not always successful translating their learning into scientific understanding. I was skeptical that Alberta students were scientifically literate at the completion of high school. I was also interested in student interpretation of scientific concepts and misconceptions about science. These misconceptions were often influenced by media and popular culture, as well as the students' life experiences (for example, the barrage of conflicting health information, the seemingly ongoing climate change debate, or dealing with the now-discredited research linking vaccines and autism). I felt it was the duty of science teachers to dispel these misconceptions and help shape student understanding so students could pick up a newspaper or go online and look at the material with a critical eye, or pursue further academic studies and communicate their ideas effectively.

As I continued my studies, my interests in student scientific literacy remained, but I shifted my focus to teachers' understandings of this part of the Alberta science program of studies and barriers they experienced in its implementation. I considered my role as a teacher and the difficulty and conflict I experienced between meeting content demands of the program of studies and addressing other aspects of science education, such as scientific literacy. I wondered if other teachers had experienced the same conflict or perhaps other challenges related to scientific literacy that I had yet to consider.

My interest in scientific literacy came from a practical, not theoretical, perspective where I wanted students to make a connection with science in the classroom and beyond. When I considered the volume of scientific and technological information individuals are subjected to each day, I felt it was imperative that citizens knew how to navigate this information, separating truth from pseudoscience. The volume of information available to students is enormous, and the manner in which students access this information has changed in recent years, particularly in regards to technology. Previously, only basic scientific information was available to the public, and more complex research was only accessible through universities and academic channels (Field & Powell, 2001). Now, information is widely accessible via the internet through formal and informal means. This availability presents many challenges including the credibility of the source, how to interpret expert data, and how to sort through information that may be misleading or misrepresented (Britt, Richter, & Rouet, 2014). Part of our job as teachers is to build students' scientific literacy skills that allow students to navigate information sources for reliability and credibility.

I share many of the same goals outlined by Duschl et al.; that "science education as currently structured does not leverage the knowledge and capabilities students bring to the classroom" (2007, p. viii), and that science courses should be structured in a manner that fosters curiosity and has students generate and ask questions and pushes them to deeper levels of understanding. I want my students to find their science courses meaningful and interesting but challenging as well. My hope for all students is they will leave high school, able to navigate their world and be productive citizens and to use their scientific understanding to be skeptical of the world in which they live.

For as long as I can remember I have loved science. I loved the subject during my schooling; I made it a part of my life outside of the classroom and eventually pursued a post-secondary education and career that revolve around science. I still love science and I love to share it with others. I consider myself to be scientifically literate; not an expert on everything but knowledgeable enough to know where to find the answers and skeptical enough not take everything at face value. I think my lived experiences in the world of science have allowed me to have a variety of different perspectives regarding scientific literacy.

Currently, I find myself most closely aligned with the National Science Education Standards definition of scientific literacy. It states

> Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions. Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately. (National Research Council, 1996, p. 22)

While I still consider scientific literacy to include the daily navigation of the world through critical thinking and evaluation, and the ability to communicate this understanding in an articulate manner, I have also had to consider other elements as well. Previously, I never reflected on the language literacy aspect of scientific literacy, thinking of it as a skill learned in

English class; however, I now not only consider scientific literacy to include the reading and writing of scientific information, but also the interpretation of graphs, charts, and statistics.

Statement of Problem

Science teachers are given the autonomy to implement a provincially mandated curriculum that includes a wide variety of goals for science education. The program vision is that

> all students have the opportunity to develop scientific literacy [through the development of] science related knowledge, skills and attitudes that students need to solve problems and make decisions and at the same time help them become lifelong learners – maintaining their sense of wonder about the world around them. (Alberta Education, 2014, p. 1)

Coupled with this are the varied definitions of scientific literacy in the academic literature (Miller, 1983). As such, Alberta teachers are left to their own interpretation of scientific literacy. Currently, research has been done identifying how teachers might implement scientific literacy in their classrooms, but little to no research has been done exploring teachers' definitions or understandings of scientific literacy. Kemp (2002) examined science educators, individuals offering instruction at a post-secondary level, including some who were involved in teacher education, but did not examine the views of teachers themselves.

At the secondary school level, there is an expectation that students graduating from high school have had the opportunity to develop scientific literacy (Alberta Education, 2014). The Alberta Secondary Science Program of Studies focuses on an extensive and varied set of curricular objectives and academic science courses terminate with a diploma exam at the end of Grade 12. This exam is not a comprehensive reflection of the students' 12 years of learning but primarily assesses content knowledge of the Grade 12 science course. Recently, the weighting of this exam was reduced from 50% to 30% of the students' overall mark. The intention was to rely more on in-class assessments, particularly those things that are difficult to assess on a multiple choice test, as well as make students more competitive at the post-secondary level with students whose school jurisdiction does not rely on standardized testing. Many of the outcomes tested focused on knowledge objectives while skill and attitude-based outcomes were to be addressed by other means. The assessment of knowledge outcomes only provides us with a partial picture of a student's scientific literacy development.

Science educators have long debated definitions of scientific literacy. The views of science educators and academics regarding scientific literacy have been widely explored but, to the best of my knowledge, those of science teachers have not. Also, challenges faced by teachers in developing their students' scientific literacy appears to be unexplored in the literature. It is important to consider that one teacher's view of scientific literacy may differ from another, and as Kemp (2002) points out, differences between educators may lead to conflict and difficulty in identifying common goals in education.

This gap in the literature leads me to ask the following research questions:

1. How do Alberta secondary science teachers understand scientific literacy?
2. Do barriers exist that impede the development of scientific literacy in high school science classrooms in Alberta?

Significance

Scientific literacy has a long history in science education. Being scientifically literate is an important skill in today's society, especially when it comes to navigating health claims, climate information, and the environment, as well as technology. To date, research has been done to explore science educators' understandings of scientific literacy as Kemp (2002) has done, but to the best of my knowledge, no one has explored the understandings held by the front line workers, the classroom teacher. In Alberta, it is important that science teachers begin the conversation about the goal of science education and that we examine our understanding of this goal. This research asks practicing teachers to reflect on their understanding of scientific literacy. It is anticipated that this may influence other teachers to think more about scientific literacy in their daily practice. Koballa, Kemp, and Evans (1997) suggest that to affect the scientific literacy of their students, teachers must "read a great deal about it, think deeply about it, and practice it to truly comprehend [scientific literacy]" (p. 31). Teachers may seek out new ways to implement scientific literacy and reaffirm this as a teaching goal. Further, science teachers will benefit from seeing there is a broad application of the term scientific literacy which can vary but can still form an important part of instructional practice.

Chapter 2

Literature Review

The goals of this investigation were to identify teachers' understandings of scientific literacy and determine if teachers felt there were barriers in the development of scientific literacy. In this chapter I will explore the historical context of scientific literacy and science education and provide a summary of the major definitions of scientific literacy. I will explore scientific literacy in the United States, Canada, and Alberta to provide an overview of educational policy. The role of teachers in the development of scientific literacy will be addressed and I will conclude with the barriers to scientific literary identified by the literature. The goal of this chapter is to present a comprehensive review of scientific literacy so that we may work towards comprehending where Alberta science teachers fit with regard to their understanding of scientific literacy.

Historical Context of Scientific Literacy and Science Education

Scientific literacy was first used formally in educational literature in the 1950s and it has had many different incarnations since (Roberts, 2007). Following the Second World War, people witnessed the destructive power of science and scientists wanted to rebuild public support of science by making it a more integral part of science education (DeBoer, 2000; Laugksch, 2000). Scientists wanted acceptance for their work and a public that had the skills to evaluate their work. The early application of scientific literacy was to develop programming for students who would not be professional scientists and also to develop an appreciation for science (DeBoer, 2000; Roberts, 2007). In the post-war period, significant scientific achievements were made and education systems responded by training students for careers in science. Minimal attempts were made to link science with everyday life; courses focused heavily on content knowledge and were "academically rigorous . . . [to] attract exceptionally bright students" (DeBoer, 2000, p. 587). By the 1970s, DeBoer reported that science and society became the focus of science education; science education was about understanding relationships between science, people, and the environment, including the nature of science concepts. By the 1980s, the focus of science education was to develop citizens who could use science and technology to contribute to global economic competitiveness but also continued to emphasize the social context of scientific education. (Laugksch, 2000). Science education also saw the integration of technology into definitions of scientific literacy (DeBoer, 2000). The emergence of Science, Technology, and Society (STS) education at this time was intended to change the focus of science education through the application of scientific knowledge and science processes in a social context. However, disciplinary content knowledge continued to play a dominant role in science education (DeBoer, 2000). Throughout the 1980s and into the 1990s, several national organizations in the United States and Canada began to develop programming documents that explicitly identified scientific literacy as a goal for science education. In 1985, in the United States, The American Association for the Advancement of Science developed Project 2061, a Science for All Americans concept that developed a very broad definition of scientific literacy that is described later in this review. The National Science Education Standards were written in 1995 with the intention that all students should have scientific knowledge, as well as understand the history of science processes and the application of science in a variety of contexts.

In Canada, there is not a national body governing education and it is a provincial or territorial responsibility as determined by the Constitution Act of 1867 (Education in Canada: An Overview, n.d., ¶2). According to the Canadian Ministers Education Council (CMEC)

> this allows provinces and territories to construct curriculum that corresponds to the needs of its citizenry, according to its unique history, culture or language demands. While this creates unique educational experiences in each province, there is some evidence that it results in different levels of achievement across the country. (Education in Canada: An Overview, n. d., ¶3)

In 1984, the Science Council of Canada, a now defunct branch of the federal government, published a document called "Science for Every Student" outlining prospective goals for science education (Fawcett, 1991). This document outlined both past goals of science education as well as future directions. The goal of this publication was to provide a framework for the development of a "first-class science education for every student" ("Science for Every Student", 1984, p. 10). This first-class science education would achieve scientific literacy for all by focusing on four main areas; 1. Science for an informed citizen, 2. Science for further education, 3. Science for the world of work, and 4. Science for personal development. Within these aims were specific goals such as linking science and technology, identifying the links between science and society, establishing a foundation for lifelong learning, approaching science critically, and promoting moral and intellectual development through content knowledge and process skills.

For scientific literacy to be developed, the authors of this publication suggested that all four aims must be balanced and science must be in harmony with other school subjects. In 1997, CMEC published the Common Framework for Science Learning which included scientific literacy goals. This vision for scientific literacy defined scientific literacy as an "evolving combination of the science-related attitudes, skills, and knowledge students need to develop inquiry, problem-solving, and decision-making abilities, to become lifelong learners, and to maintain a sense of wonder about the world around them" ("Science Assessment Framework, 2013, p. 2).

Scientific literacy has been a goal of science education for almost 60 years. It has evolved as society has changed resulting in an ever-changing definition that has included an appreciation of science to linking science, technology, and society. In both the United States and Canada significant work has been done on a national level to develop policies that make scientific literacy an integral part of science education. According to PCAP, a review of grade eight science curricula clearly identifies scientific literacy the goal of science education in all Canadian jurisdictions ("Science Assessment Framework, 2013). These science education policies have also evolved in response to changing societal demands, and scientific literacy has become the overall goal of science education.

Meaning: The Many Definitions of Scientific Literacy. Scientific literacy has "worldwide cachet," though there is no consensus about what it is and it has a lengthy history of being defined and redefined (McEneaney, 2003). It is this lack of consensus that brings tension to discussions of scientific literacy. Scientific literacy has been defined by a vast number of individuals and organizations over the past 50 years. Early definitions included conceptual knowledge, nature of science, ethics and science/technology/society (Hodson, 2002). In educational circles policy was written to be all encompassing and include all the objectives of science education into one definition (DeBoer, 2000). There does not seem to be one single definition that is accepted by all.

DeBoer (2000) completed an extensive historical overview of science literacy and distilled the following ideas regarding scientific literacy and educational reform; science education should be about the nature of science and scientific processes, it should be less about content and more about developing a public that is comfortable with science. He asserts that people do not need high levels of scientific knowledge to function in society, but a basic form, and the goal of science education should not be to be scientifically literate at the end of high school but to have the foundational skills and understanding to apply science to their own lives and to participate in society. Aikenhead's (2002) advocates the use of a science and society approach to develop scientific literacy and supports a curriculum that has personal relevance to students. While DeBoer does not tell us which approach to use to build scientific literacy skills, Aikenhead firmly supports the STS (E) approach as a student-centered approach connecting science and everyday understanding. Brown, Reveles, and Kelley (2005) identify two broad categorizations of scientific literacy; the first builds scientific knowledge to use in a variety societal situations and includes science practices, habits of mind, and science as a way of knowing. By contrast, their second categorization uses a sociocultural approach to building knowledge and using it in accomplishing the actions of everyday life.

Scientific literacy has also been subdivided by a number of authors into specific types of scientific literacy. Pella, O'Hearn, and Gale (1966) were one of the first writers to categorize scientific literacy, dividing it into six broad categories; science and society, ethics of science, nature of science, conceptual knowledge, science and technology, and science and humanities. Each of these categories was divided further into a number of supporting statements. Pella et al. (1966) work looked at the underlying principles behind scientific literacy while other authors sought to divide it into certain types of scientific literacy. Shen (1975) was one of the first writers to create this kind of distinction among the various forms of scientific literacy, dividing it into cultural, civic, and practical scientific literacy. Cultural scientific literacy is the desire to know something about science as a human achievement; civic scientific literacy is geared to participating in the democratic process and evaluating scientific information; and practical scientific literacy encompasses those skills which are useful in everyday life, such as evaluating health information or food packaging. Each of these definitions would have a useful place in education but civic scientific literacy is often seen as the minimum threshold required to function in society (Miller, 2010b). Branscomb (1981) created categories for different types of scientific literacy suggesting that the categories needed to be broad and interwoven and that people could possess more than one type of scientific literacy. These categories included professional scientific literacy, being that which scientists do; universal scientific literacy, possessed by the average citizen to function in their daily life , as well as public science policy literacy, used in decision making to name a few. Brancombe's comprehensive list seems to encompass most aspects of scientific literacy. Miller (1998) focuses on Shen's definition of civic scientific literacy as a goal for education, calling it the form of scientific literacy that allows us to read a newspaper and understand "the essence of competing arguments on a given dispute or controversy" (p. 204). Holbrook and Rannikmae (2009) also provide a thorough overview of the various definitions of scientific literacy. Their definition includes "an appreciation of the nature of science . . . consider a societal frame . . . and to embrace a socioscientific situation that provides the relevance for responsible citizenship" (p. 276).

Part of what makes the study of scientific literacy challenging is the competing, but often similar, definitions of the term. For example, Shamos (1995) offers three levels of scientific literacy built on the definitions of others: cultural, functional, and true scientific literacy. Cultural scientific literacy in this context refers not to the desire to know something, as Shen (1975) describes, but the recognition of background science to participate in a conversation, much of which is vocabulary used in the proper context. Functional literacy involves a command of vocabulary and the ability to use it in a meaningful way through reading, writing, and conversation. Finally, Shamos' true scientific literacy includes the previous two forms and is comparable to Dewey's habits of mind; the foundation of science, knowing about the theories of science, and the role of experimentation and investigation. Clearly, this hierarchy is different than Shen's, but the reuse of the term cultural scientific literacy adds to the confusion. Regarding education, Shamos sees functional scientific literacy as a reasonable goal.

Bybee (1995) uses a similar structure to organize levels of scientific literacy: functional scientific literacy, conceptual, procedural, and multidimensional literacy. In this conception functional scientific literacy is the proper understanding and use of science words, often with the emphasis in education and a minimum level of literacy. Conceptual and procedural literacy occurs when an individual understands the relationship between science concepts and processes and may consider science as a way of knowing. Finally, multidimensional scientific literacy includes a history of science including theories and laws, the nature of science, and the relationship between science and technology in everyday life. Multidimensional literacy is analogous to Shamos' true scientific literacy

Scientific literacy has also been placed along a continuum by Roberts (2007). He uses the term "Vision I" to describe literacy within science or science content knowledge, and "Vision II" to describe citizen science, or situations where citizens encounter science. He suggests that science education has traditionally been taught from a Vision I point of view but more research is being conducted to suggest that a Vision II perspective may be a more logical starting point. Lindsay (2011) is in agreement with this position; content and socioscientific approaches to scientific literacy represent the two extremes of the scientific literacy spectrum. Roberts (2007) also adds that other terms used globally to describe scientific literacy, such as scientific culture and public understanding of science, can complicate things further. Finally, he also points out that the terms scientific literacy (literacy concerning science) and science literacy (literacy that is scientifically sound) get used interchangeably even though they do have distinct meanings. Koballa et al. (1997) have also adopted a continuum model for scientific literacy with scientific illiteracy at one end of the spectrum and the nature of science and science as a cultural endeavor at the opposite end of the spectrum. In the middle of this continuum is the type of scientific literacy commonly attained in school which includes scientific vocabulary and issues, scientific method, and the big ideas of science. They also suggest that scientific literacy can be domain-specific, meaning a person may have a high level of literacy in biology but not the same degree in physics.

Other reviews of the literature by Norris and Phillips (2003) summarize the major definitions of scientific literacy in the literature identifying 11 different themes and note that no single definition includes all 11 of these features. These thematic areas include:

Table 1

Major Definitions of Scientific Literacy

Scientific Literacy Themes	**Supporting Authors**
Knowledge of the substantive content of science and the ability to distinguish science from nonscience	CMEC, 1997; Mayer, 1997; NRC, 1996; Shortland, 1988
Understanding science and its applications	(DeBoer, 2000; Eisenhart, Finkel, & Marion, 1996; Hurd, 1998; Shen, 1975; Shortland, 1988
Knowledge of what counts as science	DeBoer, 2000; Hurd, 1998; Kyle, 1995a, 1995b; Lee, 1997
Independence in learning science	Sutman, 1996
Ability to think scientifically	DeBoer, 2000
Ability to use scientific knowledge in problem-solving	AAAS, 1989, 1993; NRC, 1996
Knowledge needed for intelligent participation in science-based social issues	CMEC, 1997; Millar & Osborne, 1998; NRC, 1996
Understanding the nature of science, including its relationships with culture	DeBoer, 2000; Hanrahan, 1999; Norman, 1998
Appreciation of and comfort with science, including its wonder and curiosity	CMEC, 1997; Millar & Osborne, 1998; Shamos, 1995; Shen, 1975
Knowledge of the risks and benefits of science	Shamos, 1995
Ability to think critically about science and to deal with scientific expertise	Korpan et al., 1997; Shamos, 1995)" (p. 225)

Norris and Phillips also refer to scientific literacy as fundamental literacy (the reading and writing aspect) and derived literacy (the knowledge and understanding of science). Their work represents a small portion of the scientific literacy research that makes the link between literacy (as in reading and writing) and the skills necessary to negotiate the language of science and scientific literacy. This perspective is further supported by Hodson (2002) to include reading scientific information and documents and include the interpretation and evaluation of textual information.

The American Association for the Advancement of Science (AAAS) (1993) defines scientific literacy in the broadest sense. Their definition was part of a project to establish national benchmarks for science education designed to prepare science standards for the next generation. This scientific literacy definition included the nature of science; mathematics and technology goals; content elements for the study of the universe; functions of living things, including human biology, environmental interactions, and human interactions; as well as a history of science and common themes across science, including habits of mind ("Science for all Americans", 2013, ¶5). Each of these thematic areas are further broken down into subthemes and objectives. This definition shaped science education for over 20 years and has served as the foundation for the current model of science, technology, engineering, and math (STEM) education (Koehler, Binns, & Bloom, 2015). These organizations do identify scientific literacy as a goal, despite many outcomes that sound like content knowledge goals (Eisenhart, Finkel, & Marion, 1996). Irrespective of the definition, scientific literacy focuses on skills to develop citizens who are employable in science fields, able to cope with a changing society, able to respond to media, and able to make decisions that affect themselves and society (Hodson, 2007). Given the broad scope of these definitions, some in the science education field have become cynical and declare scientific literacy as a slogan that has lost all meaning, become politicized and useful only for garnering educational dollars (Feinstein, 2011). It is, however, still omnipresent in discussions of science education and worth some consideration as a useful end goal of a student's science education.

Scientific literacy has changed in response to changing worldview, political, social, economic, and cultural values and has evolved to meet changing agendas (McFarlane, 2012). What links these various definitions together is a basic understanding of science content and the ability to use it in everyday contexts. While there can be deeper levels of this understanding, most look to the development of responsible citizens who can make decisions and engage in public discussions of science. Although not supported by all in the literature, many of the authors see school as the foundation for developing scientific literacy skills that will continue to develop with students into adulthood. A summary of the various viewpoints from this review can be found in Table 2, organizing the terms into knowledge, skill/process, and attitude-based definitions of scientific literacy

The strength of the many articles defining scientific literacy is that multiple representations allow for individual interpretation and application. However, in an educational setting, this flexibility may be a drawback to consistent implementation and the effectiveness of scientific literacy as an educational goal may be lost. It becomes challenging for classroom teachers to ensure the goal of scientific literacy is met when one teacher treats it as understanding scientific jargon and another as responsible citizenship.

Table 2

Summary of Definitions of Scientific Literacy.

Knowledge	**Skills/Processes**	**Attitudes**
DeBoer – need to know basic science information	DeBoer – develop science skills necessary for adulthood	Pella - ethics of science
Shen: cultural scientific literacy; knowing something about science	Aikenhead – science skills and societal decision making	Bybee – ways of knowing
Shamos – cultural scientific literacy; recall of facts and scientific information	Shen - practical scientific literacy; evaluate health information	Brown, Reveles and Kelly – habits of mind, science as a way of knowing
Shamos – true scientific literacy; theories of science	Shen – civic scientific literacy; decision making	
Fensham – nominal scientific literacy; recognition of scientific words	Miller – able to read a newspaper and understand different perspectives	
Fensham – functional scientific literacy; use of scientific words	Holbrook and Rannikmae – responsible citizenship	
Roberts – Vision I; science content knowledge	Shamos – functional scientific literacy; participate in scientific discussions	
Norris and Phillips – derived literacy; knowledge and understanding of science	Shamos – true scientific literacy; role of scientific experimentation	
	Fensham – conceptual and procedural; relationship to science concepts and processes	
	Roberts – Vision II; citizen science, applied science	
	Norris and Phillips – reading and writing of science	
	Hodson – read science and interpret and evaluate	

the information

Science Educators Definitions of Scientific Literacy

Andrew Kemp (2002) completed his doctoral dissertation on the views of science educators (those in a university setting) regarding scientific literacy and asked: "what is the range and degree of compatibility of science educators' views on the concept of scientific literacy?" (p. 4). Through his research, Kemp was able to classify the many definitions of scientific literacy into three general categories: the conceptual, procedural, and affective dimensions. The conceptual dimension focuses on knowledge elements and understandings of science, the procedural is skills based, while the affective dimension is attitudinal and value based. Of the individuals participating in Kemp's research, all had elements of their definition which fit into all three categories, though the emphasis varied from each, as well as the context in which they were describing. Kemp considered the lack of consensus in defining scientific literacy a "roadblock to progress" (p. 251), referring to advances in science education.

Kemp states

> if "scientific literacy" has a number of meanings and rationales, science educators may believe they are all working toward the same goal when in fact they are pursuing different ends. Any differences in views that exist for "scientific literacy" could have serious repercussions for science education in general. (2002, p. 252)

The serious repercussions Kemp suggests include competition for scarce time and materials in classes, as well as potentially hindering efforts to improve learning in science classrooms.

The insight gained and conclusions made by Kemp (2002) have relevance to the research of scientific literacy among Alberta teachers. Kemp recommended that the views of science teachers (regarding scientific literacy) be examined to see if the opinions in his study hold true among teachers. While Kemp was looking for consensus in defining scientific literacy, his participants and the some of the literature suggested that a single definition of scientific literacy may too narrowly focus the goals of science education. Kemp also suggests that there is no evidence that scientific literacy is necessary for all citizens and some, such as Shamos (1995), believe that it is not possible for the average individual. One of Kemp's participants stated that scientific literacy is a moral goal and the right thing to do but not inherently a goal of science education, though others would certainly disagree and believe it is the primary goal of science education. Finally, Kemp recommended that scientific literacy can come from areas outside of schools, though schools should still work towards building scientific literacy, even if the population may never attain that goal. In addition to Kemp's recommendations, several other key points were identified in the research. For example, language literacy is often overlooked by those working to develop scientific literacy and science educators, including high school teachers, should examine what science people use or misuse in their daily lives and make that the focus of scientific literacy development.

Scientific Literacy in the Classroom

Science in the classroom is an outdated remnant of the industrial age and science education needs to change to keep up with issues of science and build skills necessary for the 21st century (Lindsay, 2011). Initially, scientific literacy was to be an educational goal intended for those students who were not going to pursue scientific studies after high school (Fensham, 2002). There has been little agreement however as to what scientific literacy means in relation to curriculum other than a broad educational goal (Hodson, 2002). Norris and Phillips (2003) see science literacy as both reading and writing skills, including the construction and interpretation of graphs, tables, and data, as well as science content knowledge. Others see it less about literacy and more about relating science to society. A variety of approaches have been suggested to build scientific literacy skills in the classroom. Fensham (2002) proposes using a societal approach to scientific literacy with societal issues, or issues of the media, defining the content and context of scientific literacy. The use of science in the media has also been a means of testing civic scientific literacy (Brossard & Shanahan, 2006). Aikenhead (2002) suggest that by focusing on science in media, the scientific knowledge be limited or may not stay with the students. Aikenhead is more a proponent of STS education and making connections between science and everyday understanding of science and technology using a student-centered approach. Roth (2002) is also a proponent of making science education socially relevant and personally motivating in order to build scientific literacy skills. The science for social purposes is in-line with Roberts' (2007) Vision II view of science education. Recently, another version of Vision II has evolved; Vision III is defined as citizen-based science that is "value-oriented and based on complex sustainability issues and critical perspective" (Sjöström, 2015). The consensus amongst these authors is that lasting scientific literacy is built on more than just content knowledge and that elements of personal relevance and social context help build these skills over time.

Educational Policies

Curricular documents. ***US history.*** In 1985, The American Association for the Advancement of Science (AAAS) (1993) began to reform science education with the goal of bringing science education and scientific literacy to all Americans. By 1990, a broad benchmark system called Project 2016 was written; one that could be implemented in a variety of ways, but with a shared set of goals for science education and scientific literacy. These benchmarks included that the American citizens, at the end of their public education, should be able to make sense of their world and have the knowledge and skills needed to understand science as adults. It aimed to connect science, math, and technology, not only to each other but the humanities as well. The benchmarks also suggested reducing curricular volume but still being able to address science, math, technology, society, the history of science, as well as habits of mind. This benchmark system has continued to form the backbone of science education in the United States.

STEM. Science, technology, engineering, and math (STEM) education was a term coined in 2001 to describe educational reforms that would be the key to success for students of the 21st century (Breiner, Harkness, Johnson, & Koehler, 2012). STEM education is an attempt to integrate the four discipline areas of science, technology, engineering, and math to solve real-life problems, making education less compartmentalized (Breiner et al., 2012). It also focusses on skills that cross over these disciplines, including critical thinking and problem-solving (Council of Canadian Academies, 2015). Williams (2011) further expands this list of outcomes to include the development of learners who think in different ways; can work both independently, as well as cooperatively; and who want to explore, investigate, and understand the world. STEM aims to reduce content but not eliminate it completely (Zollman, 2012). STEM education appears to have some goals that are similar to scientific literacy and it would seem scientific literacy would be one of the intended goals of STEM educational practices. The National Research Council (NRC) (2011) identifies three major goals for STEM education; the first two relate to increasing the number of students studying STEM fields and expanding the STEM workforce but the third pertains to STEM literacy. Within this are the goals of knowledge of concepts and processes to aid in personal decision making and participation in civic affairs (NRC, 2011). In Canada, STEM programming has been determined to be an important direction for education (Murray, n.d).

Meanwhile back in Canada. In Canada, scientific literacy became a national focus of science education in 1984 with the "science for all" mandate of the Science Council of Canada report, "Science for Every Student: Educating Canadians for Tomorrow's World" (1984, p. 2). In this document, it was suggested that students should have a good working knowledge of science concepts and the inquiry skills to apply them to the world around them. It was this document that would form the initial framework for many science curricula across Canada. In 1996, the science education framework was revisited by the Council of Canadian Ministers of Education to recognize the evolving nature of scientific literacy. Their new framework focused on four foundations: 1. Science, Technology, Society, and Environment; 2. Skills; 3. Knowledge; and 4. Attitude. Within this framework they also addressed what it meant to be scientifically literate. By their definition, to be scientifically literate meant one should possess scientific knowledge and use this for societal decision making and application to daily life, recognize the relationship between science and technology, be able to explore science-based careers, and recognize that science and scientific study can both help and hinder society. Further, the scientifically literate person is "able to draw appropriate conclusions from evidence and information that is provided by others and is to distinguish personal opinion from evidence-based statements" (p. 7). Within this document is the recognition that scientific literacy is hard to define and that the definition must evolve with a changing society. The Pan Canadian Assessment Program (PCAP), which measures scientific literacy in Canadian students at the Grade 8 level, focuses on assessing how the student uses their learning to real life situations ("Science Assessment Framework", 2013). In creating this assessment, PCAP creates questions that use knowledge in context, address the nature of science, and create problem-solving opportunities. It also encourages the development of inquiries by students to makes decisions and draws conclusions. Importantly, though, it recognizes that scientific literacy, and the assessment of it, need to evolve with the students ("Science Assessment Framework", 2013).

Alberta Science program of studies. In Alberta, secondary science education is guided by a provincially constructed curriculum and is the document utilized by all Alberta teachers to direct their teaching.

In all streams of high school science, the program rationale and vision are the same and it has been modelled after the CMEC framework. It is built upon the same four foundations of STS, knowledge, skills, and attitude. Like the CMEC document, there are nature of science elements, links to math and technology, and career exploration associated with all levels of secondary science education. The goal of scientific literacy is explicitly written in the program of studies as an intended purpose and outcome, first in the opening vision statement; "the secondary science program is guided by the vision that all students have the opportunity to develop scientific literacy" (AB Learning, 2014, p. 1), and then in the first foundation (science, technology, and society); "the potential of science to inform and empower decision making by individuals, communities and society is a central role of scientific literacy in a democratic society" (p. 4).

Science in Alberta has subtle streaming with students beginning science in their 10th year at the Science 10 or 14 level. Both are designed to be general science courses and cover topics in Chemistry, Biology, Physics, and Ecology. The Science 10 stream will take students to specialized disciplines of Chemistry, Biology, or Physics in their 11th and 12th years or they may pursue a general, academic science course, Science 20 and 30. Each of the 30-level sciences can be used for admission to most post-secondary programs. Students who wish to earn the required science credits for a high school diploma but without the stronger academic focus may take the Science 14/24 stream. Other streams are available to students wanting an additional academic challenge such as the Advanced Placement Program or International Baccalaureate Program or additional support for students who are in a Knowledge and Employability stream or are English Language Learners. A summary of science programming in Alberta is found in figure one. While streaming is a controversial issue in education circles for many reasons (Krahn & Taylor, 2007), in Alberta, regardless of the stream a student is in, the scientific literacy goals are the same throughout their high school programming.

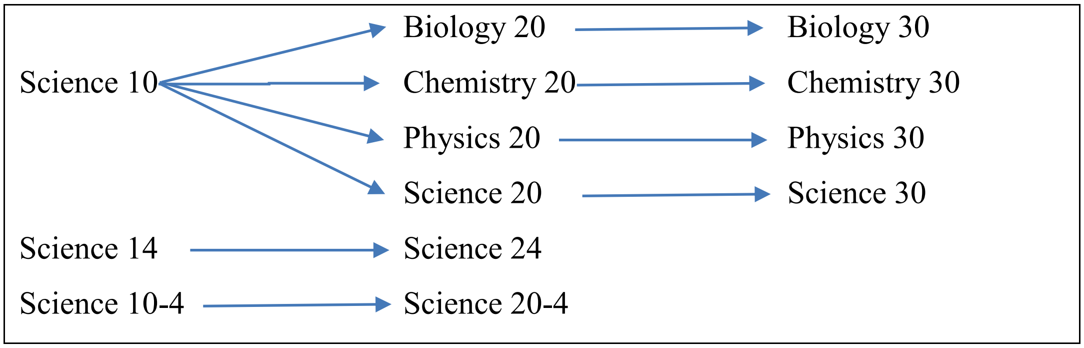

Figure 1. Science Programming in Alberta

An Albertan Context – Inspiring education. In Alberta, a shift in the way education is delivered is underway. Freisen and Scott (2013) describe the curriculum changes moving from traditional education that favor the recall of facts and testing to one that adopts a problem-solving approach. "Teachers will cultivate the natural curiosities of students and plant the seeds of life-long learning" (Freisen & Scott, 2013, p. 4). This method will be more suited for developing scientific literacy goals, but it has yet to be determined how this will be addressed in the classroom and how it will be evaluated. Recently, the Education minister in Alberta stated that all K-12 curricula would be revamped. The new direction would be a student-centered focus with an "explicit focus on the development of learner outcomes that support and reinforce 21st-century competencies across curriculum, as well as literacy and numeracy" (Alberta Education, 2016). It would seem that in Alberta student learning will be moving in a different direction, one that may be better suited to developing scientific literacy.

Teachers in Practice

How do Teachers develop scientific literacy? A study conducted by Dani (2009) identified teachers as an integral component in the development of scientifically literate citizens. Dani's research asked if teachers' purposes for teaching science correspond with scientific literacy and what contextual factors underlie their goals for teaching science. This study identified five areas within scientific literacy; 1. knowledge of science, 2. investigative nature of science, 3. personal use of science, 4. science as a way of knowing and 5. the interaction of science, technology and society, which were areas identified in definitions of scientific literacy given previously. The outcome of this study identified knowledge of science; the interaction of science, technology, and society; and the investigative nature as the significant reasons for teaching science with underlying contextual factors including major exams. Dani's research context was Lebanese private schools but this kind of questioning might be useful in an Alberta context as well.

Scientific literacy has become synonymous with science education and an overarching goal of education. In Alberta this translates into a goal of developing "in students the science-related knowledge, skills and attitudes that they need to solve problems and make decisions and, at the same time, to help students become lifelong learners who maintain their sense of wonder about the world around them" (Alberta Education, 2014, p. 1). This objective is part of all secondary science programs of studies in Alberta. This statement is open-ended so teachers and students can approach this goal in whatever ways they see fit. However, the subsequent pages of the program of studies provide detailed knowledge, skill, and attitude outcomes for students with multiple content objectives. Content knowledge has been identified in the literature as a detractor in the development of scientific literacy. Furthermore, the 30-level science courses culminate in a provincial exam, the kind of standardized test DeBoer (2000) sees as detrimental to building scientific literacy skills. The limited research on teacher interpretation and application of scientific literacy in the classroom leads me to wonder if testing and content outcomes constrain teachers from developing scientific literacy skills in their classrooms and if they see scientific literacy as a goal of the Alberta or even Canadian education system. The Alberta government is in the final stages of implementing new programming targeting 21st-century competencies and the goals of these competencies address many of the scientific literacy goals identified in other government documents such as the current science program of studies (Alberta Education, 2011). For example, this new document describes critical thinking and developing the relevant skills to make informed decisions, while the current program of studies describes problem-solving and decision making as components of the scientific literacy goals. Program changes such as this imply that scientific literacy will continue to be an underlying goal of science education.

Barriers

Within science education, challenges have always existed that were in opposition to the goal of scientific literacy. Sullenger (2005) is particularly critical that school science does little to foster scientific literacy. For example, the school science experience does not accurately reflect science in practice or the type of science that influences decision making. These differences could be seen in the types of lab experiences many students participate in where the science activity is little more than a cookbook lab or the superficial study of controversial issues. Because of this, students are unprepared to take part in society as informed citizens. Williams (2011), in speaking of STEM education, notes that an inflexible classroom design, the assessment system, and a rigid school schedule also are barriers to scientific literacy type goals. Much of science focuses on a small component of scientific literacy, focusing on the recollection of facts rather than long term retention, in addition to testing, making the acquisition of scientific literacy difficult (DeBoer, 2006; Shamos, 1995). Current content standards limit what teachers teach and standardized testing constrains natural curiosity (DeBoer, 2000). Content and testing however are a significant part of high school science courses in many regions of Canada, including Alberta. It is possible that instruction of content objectives may be a barrier for teachers in the construction of scientific literacy.

Sullenger (2005) also notes that a student's prior beliefs and experiences, language, a preferred mode of learning, and culture should also be considered when fostering scientific literacy and failure to do so may interfere with this process. Language and the understanding of the language of science is necessary for the development of scientific literacy which includes oral and written language as well as reading both text, graphs, charts, and tables (Wellington & Osborne, 2001). Compounding these challenges is the specialized skill set needed by science teachers, not just to teach science but also provide language instruction with many teachers lacking the ability to provide science-specific literacy instruction (Pearson, Moje, & Greenleaf, 2010). Glynn and Muth (1994) encourage the development of reading and writing skills by science teachers as a means to foster scientific literacy skills.

Another barrier often encountered when trying to develop scientific literacy skills is student loss of interest in science education. Glynn and Muth (1994) record that as early as elementary and junior high many students find science "hard, dull, and meaningless" (p. 1058). Osborne, Simon, and Collins (2003) note that this loss of interest is less about science itself and more about school science. This lack of interest may impede the development of scientific literacy (Swarat, Ortony, & Revelle, 2012). Specifically, the manner in which most science is taught lacks "opportunities in science for practical work, extended investigations and opportunities for discussion" (Osborne et al., 2003, p. 1074). Among undergraduate students, this lack of interest in school science stemmed from the emphasis on memorizing facts and concepts and the perceived differences between authentic science (Yang, 2010). Swarat et al. (2012) cite a number of studies regarding student interest in science. They found that topics that were personally relevant to the students and that were interactive were of the greatest interest to students.

Importance of Literacy in Scientific Literacy

Within the scientific literacy field is the element of language literacy itself. Literacy in science, or the language of science, examines how students learn to read, write, and make meaning in science (Pearson et al., 2010). Likewise, Vacca (2002) refers to literacy within science as the ability to read and write to learn the subject matter. These literacy skills may include text structure and vocabulary comprehension (Cook & Dinkins, 2015). But literacy in science presents unique challenges. Science reading presents unfamiliar content with science-specific words and definitions as well as multiple modes of representation which may include textual information, graphs, tables, or charts (Hsu, Yen, Chang, Wang & Chen, 2016). Norris and Phillips (2003) write that in a simplified sense "reading is knowing all the words and locating information in the text" (p. 229). But it should be more than knowing words. It is dependent on the background knowledge of the reader and their interpretation of the text. Pearson et al. (2010) suggest that before scientists can begin a scientific inquiry they need to read to learn background information or later be able to write papers on their results. With proper literacy skills related to reading, science skills will be supported creating a trickle-down effect into other aspects of scientific understanding (Casteel & Isom, 1994).

The lack of these types of literacy skills may impede the development of scientific literacy. Reading in science requires the same skill set as reading in other subjects. It includes learning words or terms but also having the ability to be able to connect concepts (Shanahan & Shanahan, 2012). Many students that have difficulty with science reading have trouble with reading in general (Casteel & Isom, 1994). However, the concept of content area reading is "based on the belief that general reading and writing strategies can find expression in a variety of content classrooms" and may not be effective (Brozo, Moorman, Meyer, & Stewart, 2013, p. 354).

Shanahan and Shanahan (2008) describe a specialized area of literacy they call disciplinary literacy. This type of literacy extends beyond basic and intermediate reading skills and focuses on the specialized reading needed for each subject area; for example, the type of literacy necessary to understand an English book varies significantly from that required for a Biology text. It has been reported that teachers do not prepare students for this type of literacy, in part because they focus on content outcomes, despite the fact that science careers employ these kinds of skills regularly (Shanahan, Shanahan, & Misichia, 2011). Moreover, they lack the proper training to do so. The area of literacy in science presents particular challenges to both students and teachers alike and may impact the development of scientific literacy.

Conclusion

Since it was first used in the late 1950s, the word scientific literacy has evolved over time. Much of the time its evolution corresponds with changing goals of science education. These definitions have included the type of literacy needed to cope with daily life as well as the kind of scientific literacy possessed by professional scientists. Currently, scientific literacy is broadly defined to include knowledge outcomes, skills and processes, and finally, attitudinal dimensions. Likewise, the purpose of science education has evolved throughout the years. Initially, it was to prepare students to enter the field of science, then it expanded so all students could have some understanding of science. It has continued to be the goal of education across North America with a broad definition that incorporates multiple science objectives. While barriers do exist to the development of scientific literacy, it continues to be a worthwhile goal of science education.

The definitions of scientific literacy in the literature try to establish its necessity for society given a particular moment in time. The different degrees of literacy attained by individuals are often such because of the person's particular context. In education, the definition of scientific literacy is broad and sets out to accomplish many goals under the umbrella of a single term, potentially disregarding differences in teaching context. To be a useful goal for teachers and students, a clear understanding of the term and its role in science education must be established to ensure some level of consistency, regardless of teaching context.

Chapter 3
Research Methods

Introduction

As an integral part of the Alberta Science Program of Studies, the development of scientific literacy is an intended goal of science education. This study identifies the understandings of scientific literacy held by Alberta secondary school science teachers and explores any barriers and challenges to scientific literacy instruction identified by teachers. In this chapter the research design, trustworthiness of the data, and the ethical considerations will be described, as well as the delimitations of the study.

Methods

Research method and design. The research method used for this study was a semi-structured interview approach. The interview questions can be found in Appendix A, but the primary focus of the questions was to determine:

1. Understandings identified by the teacher as being associated with scientific literacy and
2. Barriers and challenges perceived by the teachers in developing scientific literacy in their students.

Given these questions, a qualitative approach was taken. A qualitative or descriptive method will be used to examine the question of how teachers describe scientific literacy and barriers to its implementation. This approach will attempt to answer how Alberta Secondary Science teachers define and categorize scientific literacy and any perceived barriers to the development of scientific literacy in secondary science classrooms in Alberta as identified by teachers.

When research answers are not easily arrived at by a quantifiable or statistical method, a qualitative approach should be used (Strauss & Corbin, 2008). Qualitative methods seek to develop questions that have not yet been asked and a descriptive approach recognizes the "subjective reality" of human experiences and attaches meaning to them (Holloway & Wheeler, 2002, p. 7). This form of qualitative approach will personalize the data and tell the story behind the data, providing depth and richness to the story that could not be measured using a quantitative approach. Because of the broadness of scope in defining scientific literacy and the overlap of individual definitions between categories, a qualitative approach will allow many of these definitions to be addressed. This project will utilize a semi-structured interview format to address the research questions. Interviews are useful in allowing the researcher to control the line of questioning but a semi-structured format creates allowances for extended discussion and emergent questions (Creswell, 2009).

A prepared set of general demographic questions and a fixed set of research questions will invite further open-ended dialogue. "Conversation is a basic mode of human interaction" (Kvale and Flick, 2007, p. 4) and will encourage subjects to "symbolize their experience through language" (Seidman, 2006, p. 8). Seidman also suggests that interviews are stories and people must be reflective of their experiences when sharing these stories. Reflection and the interview format itself give the opportunity for clarification of comments, follow-up questioning, and the extension of statements made by the interviewee (Kvale and Flick, 2007). Given the social and reflective nature of education, this approach seemed like a logical fit for this investigation.

The interview format will be modelled after the research of Kemp (2002). Kemp's research used open-ended interview questions to determine science educators' perspectives on scientific literacy. This project was intended to be exploratory in nature, identifying local teachers' views on the topic of scientific literacy. A convenience sample was used given challenges regarding accessibility to interviewees.

While the interview transcripts served as the primary source of data, field notes taken during the meeting, as well as off-the-record discussion helped develop a snapshot of each teacher's particular perspective of scientific literacy.

The data was analyzed according to pre-determined themes associated with the literature, specifically the work of Kemp (2002). A further discussion of these items is found in Chapter 4. These themes included three major areas of scientific literacy: 1. Knowledge of science, 2. Skills and procedures associated with science practice, and 3. Scientific attitudes. The other categories were related to the barriers related to the development scientific literacy in the classroom.

Setting. The study took place at various locations throughout Edmonton and one location in rural, Central Alberta. The setting was selected by the interviewees to create a comfortable climate for the interview to take place. The meetings took place in the teachers' classrooms outside of instructional hours, in their homes, at coffee shops, as well as other educational offices. Teachers selected the meeting dates and times that would best fit into their schedule.

Demographics. In this study, eight secondary science teachers were interviewed. The sampling procedure was a convenience sample generated through an email request and social media request for high school participants. The subjects were selected based on their willingness to participate in the study.

Data Collection: Interviews

Teachers were recruited between July 2014 and January 2015 through social media and email. A request for participants and contact information was sent to current teaching colleagues from a school-based email list, as well as through social media calling for the recruitment of science teachers interested in participating in this research project. Through the school-based email, the letter of introduction outlining the project and consent form were attached to share with interested parties. Individuals whose names were generated through social media were sent these documents after their initial contact with the researcher. Following these early contacts, arrangements were made to meet with teachers at a time and location determined by the participant. Participants were asked to be available for a 30- to 60-minute semi-structured interview and a self-guided follow-up to review their interview transcript. All interviews were conducted during face-to-face meetings. It was anticipated that a sample size of 10 to 15 teachers would be generated; however, the final sample size was eight teachers. Participants followed up their interview with a review of their transcripts to identify errors, omissions, or to clarify points.

Trustworthiness

"Without rigor, research is worthless, becomes fiction, and loses its utility" (Morse, Barrett, Mayan, Olson, & Spiers, 2002, p. 2) and thus methods to ensure the validity of the study results are imperative. In this study, the primary means of validity was through the use of member checks. Participants were questioned and then responses were summarized back to the subject during the interview for clarification and accuracy. As well, participants were given the transcribed version of their interview so that they could evaluate and modify their statements. While Morse et al. (2002) criticize the use the member checks as a measure of validity, others such as Creswell (2009) and Lincoln and Guba (1985) emphasize their effectiveness as a validation procedure. It is worth noting that Creswell does not consider the review of raw transcripts by participants as member checking, but rather the assessment of a "polished product, [such as the final report]. . . [or] a follow-up interview. . . [with] an opportunity for them to comment (2009, p. 191). In this study, only the transcripts were reviewed.

To provide a reliable data set, transcripts were sent back to the participants for their review. The credibility of data is built through the sharing of data (Brown, Stevens, Trobiano, & Schnieider, 2002). In reviewing their transcripts, participants could add or delete statements or offer clarification to statements they had made, adding to the trustworthiness of the information and preventing misunderstandings. An additional layer of credibility could have been added if the coded transcripts were returned for review, but it was not possible at the time of the study. Consistency in coding was attained by using an existing framework developed by Kemp (2002) and discussed in greater detail in the next chapter. Coding statements to the knowledge category, words like concepts, vocabulary, big ideas, and terminology were used and the intention of these words was defined. These terms are consistent with Kemp's conceptual dimension. Kemp's second dimension, the procedural dimension, identified skills and procedures used in science. Similarily, for my coding I looked at the application of scientific information to both everyday life and new contexts. Finally, with the attitudinal dimension, I paralleled Kemp's categorization and included an appreciation of science, a general interest in science, and the shared values of science, such as skepticism and open-mindedness.

For the second research question addressing barriers, participants were asked if barriers existed and open coding was used to categorize these barriers. A review of the transcripts identified three general categories of barriers that were consistent in the transcripts. A summary of the knowledge, skills and processes, and attitude and barrier codes can be found in Chapter 4.

Ethical Considerations

In accordance with the policy of the University of Alberta, Faculty of Graduate Studies, appropriate ethical approval was obtained from the Research and Ethics office of the University of Alberta. This clearance ensured the proper protection of: the rights of the study participants including voluntary participation, anonymity during the study, the written thesis and subsequent materials in the future, the right to withdraw from the study, as well the management and security of collected data. Participants were given an information letter before being interviewed and gave written consent at the time of interview.

See Appendix B for information letter and letter of informed consent

See Appendix C for ethics approval letter.

Delimitations

Criteria for inclusion in the research entailed the following: high school teacher, a licensed teacher in Alberta at the time of the study, with one or more years of teaching. Teachers were included if they had a general science or a discipline-specific background such as exclusive Chemistry, Biology, or Physics. Teachers who were not currently teaching but had taught in the last year were included in the research. While several teachers with junior high teaching experience were interested in participating, participation in this study was delimited to high school science teachers. Junior High teachers were excluded from the study because of differences in curricular demands in comparison to Senior High teachers. Further, teachers in both the Public and Catholic school boards were eligible to participate. Finally, participants were required to have recent teaching experience, with a minimum of one year of science teaching.

Chapter 4

Results and Data Collection

This chapter will summarize the definitions or understandings of scientific literacy as identified by eight Alberta high school teachers. The purpose of the investigation was to examine the manner in which high school teachers in Alberta defined scientific literacy. Secondary to the main research question was the identification of barriers or challenges teachers may experience when integrating scientific literacy into their daily teaching.

These teachers were primarily from the Edmonton area, though one teacher represented rural Alberta. The sample was divided evenly according to gender with four female and four male teachers making up the sample. Years of experience ranged from 6 to 28 years of science teaching experience, with the average being 15 years of teaching experience. The majority of the sample held undergraduate degrees in both science and education, though one teacher had a third degree in arts. Two teachers had one degree—a Bachelor of Education. The school sizes varied across the sample from under 500 to over 1,500 students but most schools were in the 1,000 to 1,500 student range. With the exception of one school, all were urban schools, though the urban schools represented a variety of contexts including strong academic focus, arts-focused schools, schools with a large English Language Learners (ELL) population, and a school with a transient school population. From this sample, all science courses presented in the Alberta science program of studies were represented including Science 10, 14, 24, 20, 30, Biology 20, 30, 35, Chemistry 20, 30, and Physics 20, 30. Advanced Placement and International Baccalaureate teaching were included in this. Many of the teachers also had taught non-science courses throughout their career. A summary of the teacher demographic information can be found in Table 3.

Table 3

Demographic Summary of Secondary Science Teachers

Participant	Gender	Years of Teaching Experience	School Size	Degrees Earned	Subjects Taught
Mr. V	M	15	Less than 500	BEd	General Science Chemistry, Physics
Ms. S	F	14	501-1000	BSc BEd	General Science, Physics, Biology, regular and IB
Mr. P	M	15	501-1000	BSc BEd BA	General Science, Biology, Physics, regular and IB
Mr. S	M	16	1001-1500	BSc BEd	General Science, Biology, Physics, regular and IB
Ms. G	F	6	Less than 500	BSc BEd	General Science, Chemistry
Ms. T	F	18	1001-1500	BSc BEd	General Science, Biology, Chemistry
Ms. H	F	9	1001-1500	BSc BEd	General Science, Biology, Chemistry regular, AP and ELL
Mr. K	M	28	Less than 500	BEd	General Science, Chemistry, Physics 10-30 levels, regular and IB

Framework of Analysis

The framework of analysis was modelled after Kemp's (2002) doctoral research and terms identified in the Alberta Science Program of Studies. Kemp uses three "dimensions of scientific literacy" (p. 125) to classify his data: conceptual knowledge which included knowledge of scientific concepts; procedural dimension, including "procedures, processes, skills and abilities"; and the affective dimension, "feelings, attitudes, values and dispositions." To be consistent with the vocabulary in the Alberta Science Program of Studies, I refer to these categories as "knowledge," "skills and procedures," and "attitudes."

Pre-defined codes in the knowledge category drawn from Kemp's framework included "knowledge of scientific concepts" (2002, p. 125), "a broad range of scientific concepts," "vocabulary," "relates to technology" (p. 143), and "understands models and theories of science" (p. 160). Other phrases Kemp associated with knowledge dimension include "awareness of science-related issues" (p. 180), "knowledge of science concepts . . . in an interdisciplinary context" (p. 192), and "basic knowledge and understandings of science (at a newspaper level)" (p. 200). Relating also to the Alberta Science POS are an understanding of specific knowledge outcomes and the understanding of "laws, theories, models and principles that are essential to a[n] . . . understanding of science" (p. 4) as well to interpret and extend this understanding.

Summary of knowledge codes.

Table 4

Summary of Knowledge Codes

Code	Statement	Source
Broad conceptual knowledge	"some of the big themes or ideas in science is what I would think of in terms of literacy, and obviously you can't know all the details about a particular field of science"	Mr. S interview
Science vocabulary	"using the proper vocabulary"	Ms. H interview
Link between science and other disciplines, including technology	"I think definitely helps students <u>having more than one discipline</u> in science on their scientific literacy."	Ms. H interview
Awareness of science related issues	"know <u>what's going on in the field</u> [science]"	Mr. S interview
Basic knowledge outcomes	"They have a <u>basic understanding</u> of chemical concepts like rates of reaction and diffusion, only in <u>simple terms</u> not osmosis but diffusion"	Mr. V interview
Knowledge of scientific laws, theories, models and principles	"being able also to pull on <u>theories and concepts</u> that are currently <u>accepted by science</u>."	Ms. H interview

To identify codes related to skills and procedures, Kemp (2002) identified scientific procedures, processes, skills or abilities,such as the use of science in one's everyday life, communicate science to others and understand scientific communication (and "answer questions through observation and experimentation, including observing, collecting and interpreting data" (p. 136) scientific method). Also included in this was applying science to societal and personal needs, such as decision making (including citizenship, health and safety or job-related topics) or "interpret and understand science messages in popular media" (p. 148), and "self-learn more science" such as after formal education has ended (p. 143). Additional elements specified reading and writing of science and problem-solving, as well as using "careful methods," "logical reasoning" (p. 192), and identifying reliable sources of information. The Science Program of Studies focuses on science skills such as "answering questions, solving problems and making decisions," as well as applying science and communicating scientific information.

Table 5

Summary of Process and Skills Codes

Code	**Statement**	**Source**
Scientific method	"I would focus on, hypothesis, conclusion, and presentation of data"	Mr. P interview
Problem-solving, reasoning and argumentation	"the importance of defining clear questions to have a discussion and then finding supporting information"	Mr. K interview
Uses science in everyday life	"I think that even the basic high school sciences allow you to make personal and societal decisions that hopefully are well [?] and well resourced"	Ms. S interview
Applies scientific understanding to new contexts	**"**think you need to take the knowledge that you learn and apply it to situations outside of the classroom"	Ms. H interview
Communicates scientific information	"We do a lot of communication where they have to talk back and forth to each other or talk in groups and just listening to their, or their written responses as well shows what their thinking is."	Ms. S interview
Integrates knowledge	"If we're having them evaluate or analyze material their knowledge could come through from that"	Ms. T interview
Self-learns science	"wanting to pursue or enhance their own scientific literacy is when they find stuff, bring in stuff."	Mr. S interview

Finally, the context of the attitudinal dimension was coded based on “interest in science, mutual respect, and attitudes that support inquiry” (Alberta Education, 2014, p. 3). Kemp (2002) associated “feelings, attitudes and dispositions” (p. 125) as part of the affective dimension. Further to this, phrases such as “motivated to learn more,” “keeps science knowledge current,” “interested in science and finds it pleasurable” (p. 136), a skeptical mind, and “appreciates science itself,” both for its positive and negative elements (p. 148) were used to code the interview transcripts. Also within this dimension were values such as a curiosity, open mind, objectivity, and skepticism, values that were shared with practicing scientists.

Table 6

Summary of Attitude Codes

Code	Statement	Source
Appreciates science and is interested in science	It’s interesting ‘cause a sense of wonder or a sense of inquiry is critical for that to develop after you get out of a classroom. It’s hard, I try to now but it’s a totally different zone but when I was in junior high, the most important thing for me and I joked about it but it’s true, was at the end of junior high if you didn’t hate science then I had succeeded. If they were like that’s cool or they wanted to know more and that would feed on itself.	Mr. V interview
Motivated to learn more/interested in keeping up to date	“maintain an awareness and a knowledge of current trends and discoveries in science”	Ms. S interview
Shares Values of Scientists; open-minded skeptical, curious	“I wonder about problem solvers are more effort driven, that everything’s possible, they’re open to new ways of thinking”	Mr. V interview

Findings

In this section, the findings will be summarized in the following format: first, an overall summary of each participant will be given, in some cases including a statement about their definition of scientific literacy and then each of the theme areas will be summarized by knowledge, skills, and process and attitudes. Finally, barriers to scientific literacy will be summarized by the following three themes: student-related barriers, teacher-related barriers, and curricular-related barriers.

Research Question One:

What are Secondary Science Teachers Understandings or Definitions of Scientific Literacy?

Mr. V's summary. Mr. V was a science teacher in an institutional setting, teaching science to a transient population of students from Grades 10 to 12. He had been teaching science for 13 years. Mr. V believed scientific literacy was an important part of high school education and was intended to inform students about "what is going on in the world and how important it is to learn what is going on." At the end of their formal education he believed students should have a "basic understanding" of science concepts. Mr. V's definition of scientific literacy was "a functional knowledge of science vocabulary and the skills and the ability to apply them in a variety of settings." To Mr. V it was important that students develop a positive attitude towards science and it was less important that they have extensive conceptual knowledge.

Knowledge. In his teaching, Mr. V focused on "big concepts" and believed this was necessary to not to lose students in "the details or [get] caught up in the memorization of [these] fine details." He believed that this "basic understanding" could help students link science to stories occurring in the news. Mr. V also tried to incorporate science vocabulary "as often as I can" to help "fill them in [so] they're not adrift" when it came to his science lessons. The vocabulary of science was a major component of Mr. V's understanding of scientific literacy and he believed a "functional knowledge of science vocabulary and the skills and abilities to use them in a variety of settings" would be the key points to the development of scientific literacy. He believed that basic science can be easy to learn and likens scientific understanding to "learning a new language"; if a student can learn this language, it gives them the ability to understanding science in one's day-to-day life. With this understanding of language and vocabulary comes the ability to understand the "connections between all of [the] different disciplines" including math and science, both understanding how to link subject matter, as well as the attitude that science shares many connections with other areas.

Skills and process. Mr. V saw the importance of scientific literacy in the education system being related to everyday life and giving students the background to make "political and economic decisions that [may] affect them." He linked this specifically to the local economy in Alberta and wanted students to understand how science and technology could contribute to the economy. Mr. V felt that by "constantly referencing the media" you could get students talking about "what's going on in the world" and how important it was they know what's going on. Within this teaching of applied science is a contextual approach that includes the use of a "hands on" activities to make science more "tangible" to the students.

Attitudinal dimension. Mr. V made some statements associated with the attitudinal dimension of scientific literacy. He saw the scientifically literate individuals as "problem solvers," "open to different solutions [to problems and] open to new ways of thinking." With this came a willingness "to listen to others" when exchanging ideas and their desire to know more. Mr. V suggested that literate individuals possess "a sense of wonder or a sense of inquiry" and that this attitude was critical to maintaining scientific literacy outside of formal education. He believed that with this as a goal, individuals might want to know more about science, and as one learned more they would want to know more, creating a dynamic cycle of learning. He believed that to be scientifically literate one must be "willing to ask questions" and shared some of the values of a scientist by "reading from a variety of sources." He thought scientific literacy was evident when, during student "conversations," science topics become a part of those conversations or when students "want[ed] to know more" and didn't "hate science."

Ms. S's summary. Ms. S had over 14 years of teaching experience and had recently moved from the classroom to an administrative position that specialized in student assessment. It was clear from Ms. S's interview that her understanding of scientific literacy was both a process and skill-based endeavor with attitudinal dimensions and not reliant on knowledge outcomes. In her personal definition of scientific literacy, however, she described "a foundational knowledge and understanding of the laws and guiding principles that apply to the universe and the ability to apply those to new situations." In this regard, she recognized a certain level of basic knowledge was required but not something she emphasized to the same degree as the other categories.

Knowledge. Ms. S did not emphasize knowledge-based outcomes as part of her understanding of scientific literacy. She did believe there was a "baseline of knowledge" that was required to function in society but was not sure if this could be quantified. She did feel that a basic understanding of high school science would be enough for an individual to function quite well in society. Ms. S felt that curricular content, the knowledge-based outcomes, were the same across the province and differences in understanding might come from the way the teacher chose to "engage the student." It was important to Ms. S that students had some "background knowledge" and that scientific literacy may be driven by the "breadth of knowledge" contained in the curriculum but saw this as foundational only and not an emphasis for producing a scientifically literate individual. She suggested these types of "fundamental pieces" allowed students to take their understanding to the next step. While Ms. S did not emphasize knowledge when discussing her understanding of scientific literacy, she implied that it was in the background and attended to by the knowledge outcomes in the provincial curriculum.

Skills and process. For Ms. S, science skills and processes made up the major portion of her understanding of scientific literacy. These skills and processes took many forms, for example, being able to apply science knowledge "to make personal and societal decisions" and "learning to question." In the classroom, Ms. S tried to make the laboratory work "hands-on and inquiry-based." Her intention with class activities was to develop "lifelong learning skills" that students could apply in other settings. Ms. S stressed at several points during the interview that "applying [learning] to new situations" was important. Applying learning could include creating a lab and determining the components of the lab or the "scope and sequence of an investigation," such as manipulating variables and responding variables or using these strategies to "problem solve." Translating scientific information and using various forms of communication also defined Ms. S's understanding of scientific literacy. In the classroom, students "talk[ed] in groups," or "back and forth to each other" as a means of collaboration and discourse, or they may show their scientific understanding through "written responses." While Ms. S included these various skills in her definition of scientific literacy, she saw it not so much as a "process" but as a skill set, comparable to being able to "read and write" and necessary to "analyzing the world and hopefully solving its problems or for the future." Part of Ms. S's most recent teaching assignment was with a highly academic stream with programming that emphasized student inquiry.

Attitudes. Attitude or personality traits were reinforced by Ms S as being associated with being scientifically literate. She identified individuals that had critical thinking skills and were "resourceful," "objective," and "logical" as being essential characteristics of the scientifically literate individual. Overwhelmingly though, Ms. S emphasized being "curious" as essential, and while she noted some students were naturally curious, she believed it was the job of the teacher to create a curious classroom. To Ms. S, science is "doing" science, not "mundane vocabulary sheets and seated work" but engaging material that can "flip the switch" for some students. She suggested that a classroom "driven by questions, not answers" could foster curiosity, and that if you could not spark the curiosity in the students "almost everything thereafter is pretty much lost." She encouraged her students to "reflect" when given a scientific question or task so that they could "delve into their current beliefs" about science.

Ms. S stated that some students, in addition to being naturally curious, may also be "natural inquirers" and that this may come from the student's experiences at home or from experiences outside the classroom. For students who are not natural inquirers, Ms. S suggested the teacher can build engaging experiences that foster inquiry skills and make it an "interactive process . . . that's working with them [the students] to discover where they are and where they want to go".

Mr. P's summary. Mr. P had been a practicing teacher for 13 years but came to education as a mature adult after several years in the social work industry. These pre-teaching experiences helped shape his understanding of scientific literacy being primarily skills-based. During his interview he described the many ways he tried to build scientific literacy skills. Throughout the interview, Mr. P provided various examples of activities and teaching strategies that emphasized his beliefs regarding scientific literacy. Mr. P defined scientific literacy as knowing what science was, doing science, and being skeptical. I would identify Mr. P's understanding of scientific literacy to be skills and process based with an emphasis on the scientific method.

Knowledge. Mr. P made a special point of spending the first few days of each semester working on scientific literacy skills. In this 2- to 3-day period he started with a definition of science and then described the components of the scientific method often used by high school science teachers which included a problem statement, hypothesis, materials, procedure, data collection, analysis, and conclusion. He used this as a method to ground students in the elements of scientific literacy he considered important. He also used this method to help address pseudoscientific issues and build a healthy sense of skepticism in the students. He recognized that this 3-day side trip came at the expense of content information, but felt that both the process of science and "to know what science is" were worth it. In considering who was scientifically literate, Mr. P suggested a hypothetical scenario that students with a grade over 70% were likely scientifically literate but those below 50% were not. In further discussion, however, he did not link content knowledge, as measured by an exam, with scientific literacy. When questioned further on this, Mr. P suggested that some students had mastered the content but they were not getting the bigger picture of science and that scientific literacy was not something that could be measured by a number.

Skills and process. Throughout the school term, Mr. P reinforced the scientific process of how to write a hypothesis, "what a variable is and what valid reliability means." In building these skills, he often focused on one element of the scientific method like writing a "good hypothesis," a strong conclusion, and clear presentation of the data. He saw applications of this for his students in the world of work, by having the skills necessary to "problem solve," regardless if they end up in a science related career or not. Further to this end, Mr. P liked to keep things open ended and have the students "draw their own conclusions. Other process elements of significance included identifying "relationships between variables" and making connections between the three high school sciences. Because Mr. P worked at building process skills in all grades, from Grade 10 to 12, he saw scientific literacy as developing over time: "people become scientifically literate the longer they live." So he saw his role as significant in developing the foundational skills that students could carry with them throughout their lives.

Attitude. The attitudinal dimension of Mr. P's understanding centered on two characteristics: skepticism and confidence. Mr. P felt that the scientifically literate have a "healthy dose of skepticism" that could be used to address the pseudoscientific and pop culture science references as well as for solving scientific problems. Throughout his life, Mr. P had been encouraged to be skeptical and to ask questions. Regarding confidence, Mr. P stated that the scientifically literate are "not afraid to say I don't know" and they articulate when they need more information. I associated these statements with being confident, but one could also define these as comfortable with one's self.

Mr. S's summary. Mr. S had 16 years of teaching experience and within this experience, several years had been spent working in student assessment. Before this, Mr. S had taught in several larger Edmonton high schools and had taught secondary school overseas. Mr. S saw scientific literacy as having both a strong skills and procedural dimension, as well as many points in the attitudinal dimension but did not focus on knowledge. In describing Mr. S's understanding, I could see that these were cruicial elements and that he wanted his students to take these things beyond high school.

Knowledge. In describing scientific literacy, Mr. S recognized that some "basic knowledge" is required but did not articulate what this basic knowledge entailed. He did suggest that a "big themes" approach would be effective and described a scientifically literate person, not as one who knew a great deal about one topic but more someone who knew something "about lots of different science topics." With this basic knowledge he felt students should gain an "awareness and knowledge of the current trends and discoveries in science."

Skills and process. Making connections between science and society, understanding ethical issues in science, and understanding how a scientific concept might impact a student's life were repeatedly mentioned by Mr. S. Major portions of Mr. S's understanding of scientific literacy were to bring scientific concepts into the applied realm. Mr. S spoke several times about the value of students "understanding issues around science" so they could make decisions and practice good "citizenship," or pick up a newspaper and evaluate the information with a critical eye. Being able to use scientific information in high-level thinking such as evaluating "whether or not you should buy a GMO fish or tomato from the grocery store," and not just knowing what a genetically modified organism is factored into his understanding of scientific literacy. In his classroom, Mr. S encouraged students to use popular media to bring issues to class and then would expect students to be "critical thinkers" and evaluate the material. Mr. S wanted his students to "understand what the field of science is about and how scientists go about doing their work." With this in mind, Mr. S had students take basic understandings and ensure they could "apply it, synthesize it, [and think about it]" forming their own opinions.

Attitude. A number of different attitudinal dimensions were part of Mr. S's understanding of scientific literacy. Firstly, he identified an "interest in science" both inside and outside the classroom as vital. For example, a person who would be willing to pick a science trade publication and read it for pleasure and be able to have a good understanding of what they were talking about. This interest extended to students being "passionate about science and [wanting] to learn more about science at the high school level." Mr. S felt that by high school, many students were "turned off by science" and had a "lack of confidence that becomes lack of motivation." In his opinion, increasing a student's motivation by choosing topics of interest and getting them excited by doing lots of science activities, particularly hands-on activities, could build confidence and was important to the development of scientific literacy.

Ms. G's summary. Ms. G was the only participant from a rural school district and had the least teaching experience with 6 years. In her teaching context, literacy, not specifically scientific literacy, was a school focus and thus her responses focused more on reading and writing in science. While Ms. G did identify knowledge, skill, and attitudinal components of scientific literacy, these components still referred back to the idea of basic literacy skills. While she did state that "highly educated" individuals were more likely to be scientifically literate, she did not liken this to specific knowledge outcomes besides having a well-developed vocabulary. With this focus on literacy, I would categorize Ms. G as having primarily a knowledge focus, but because of this attention to literacy, her perspective stood apart from the other participants.

Knowledge. Being able to understand the words of science and "understand what you are reading" was an important part of Ms. G's definition of scientific literacy. By being able to comprehend science words, she felt one could navigate the world given the high degree of accessibility to information currently available. Ms. G implied that the act of decoding words and linking them to everyday instruction was important for scientific literacy but often "most of literacy [was left] to the Humanities teachers." She focused on the students' abilities to use science language in the immediate sense, such as using these skills on a provincial achievement test. Ms. G felt that knowing "key words" and developing vocabulary would make science more accessible, stating that "if you don't understand what you are reading you are at a disadvantage" and that "science is actually easy . . . once you can read it."

Skills and process. In Ms. G's opinion, relate-ability and the application of scientific understanding to new contexts were what distinguished some individuals as more scientifically literate than those who could not translate these understandings. These were the only skills and process elements that Ms. G mentioned during her interview and these related to how you could determine if someone was scientifically literate. These did not relate to what scientific literacy elements she focused on in her classroom.

Attitude. Ms. G did identify some other elements not linked to language literacy in shaping her understanding of scientific literacy. These included elements related to "appreciation of learning" and being "willing to go beyond and above" what was expected. Being an inquirer, questioning information, looking into studies, and always wondering were characteristics she attributed to those who were scientifically literate. Someone who had a "love" of science or made science a "personal passion" were described by Ms. G as having scientific literacy. She recognized that science needed to get to the point that it "means something" to the students. Ms. G suggested that some of this attitudinal dimension was something that may be developed outside of the classroom through their parents and that parental influence may help develop an interest in science before the student even entered the classroom.

Ms. H's summary. Ms. H was an experienced science teacher that had taught in multiple streams of science, including ELL science. Her experience with ELL learners helped shape her understanding of scientific literacy. Ms. H saw scientific literacy as something that could be developed in varying degrees, with some individuals being more literate than others. Her definition of scientific literacy included being "able to understand and communicate science topics using proper vocabulary and being also able to pull on theories and concepts that are currently accepted by science."

Knowledge. Language and vocabulary were important to Ms. H's understanding of scientific literacy. A scientifically literate person can use specialized science terminology that "not everybody else would understand." In the classroom, as students may not be familiar with the language of science, Ms. H suggested helping to familiarize the students with the vocabulary by using it in a proper context and a consistent fashion. Ms. H believed understanding the language of science was one of the bigger challenges related to scientific literacy. As part of their science learning, Ms. H suggested students draw on scientific "theories and concepts that are currently accepted by science" and "using the proper vocabulary" to communicate to others.

Skills and processes. The focus of most of Ms. H's understanding of scientific literacy centered on the skills and processes dimension of science. She wanted students to take "knowledge that [they] have learned before and apply it to situations outside the classroom." This application of knowledge related not just to the student's current learning situation, but also to their lives after high school. Ms. H saw the application of knowledge as a useful skill in industry, specifically industry in Alberta, but also in one's daily life. She believed that one needed to keep building upon their high school science experience to enrich their scientific understanding. For example, Ms. H suggested reading literature that was scientific in nature and taking information from it was important for encouraging scientific literacy, although she noted that this was also a key component of basic literacy as well. Within the classroom, Ms. H stressed that students should be "able to communicate using the proper language," be able to interpret scientific questions, and interpret laboratory experiences, all in a manner that the teacher could understand.

Attitude. Having an "interest in science" was mentioned by Ms. H as possibly making a person more scientifically literate over another individual, perhaps because these persons were more inclined to "pursue topics that are scientific" through the reading of science literature. In this context, Ms. H did not elaborate if the additional vocabulary gained, knowledge elements, the skill of reading, or the interpretation of that piece of literature were what was linked to scientific literacy. Attitudes shared by scientists formed another part of Ms. H's understanding. Being able to question was one of these skills, specifically questioning "what makes things the way they are" by using scientific understanding and principles to develop this understanding, or challenging ideas that an individual may not have thought to challenge in the past. Finally, Ms. H stated that studying "more than one discipline in science" could be a part of scientific literacy because there was an overlap [in concepts] between the disciplines and identifiable links between these concepts.

Ms. T's summary Ms. T was the most experienced female teacher in the group. She taught at a culturally and economically diverse urban school. Ms. T believed that scientific literacy was an important goal of science education, not one that was necessarily explicit in instruction but more subtly "woven throughout all of the different [science] courses." Scientific literacy was an expectation she had of her students, yet she stated she did not believe them to be scientifically literate at the end of high school. In developing a personal definition of scientific literacy, she included basic scientific concepts that were scaffolded through the educational system, awareness of variables, and alternative perspectives with general reading comprehension skills that they used on a day-to-day basis. Of the eight participants, Ms. T seemed to have the most balanced understanding of scientific literacy drawing on all three areas more equally than other participants.

Knowledge. Ms. T was tentative at first in her understanding of scientific literacy but as the interview progressed she was able to identify several elements that defined her understanding of scientific literacy. At the root of her definition was the component of knowledge; having “base knowledge” or “background knowledge that included “facts” and “information,” including “basic scientific concepts.” She identified the Alberta Science Program of Studies as a key source for this background information and that “understanding the curriculum” was an important source of scientific literacy. Ms. T acknowledged that some students came to class with an already developed base of background information, yet other students, depending on their situation, may require information be “backfill[ed]” to bring them to the same standard as other students in the class. Because Ms. T’s school had students from diverse backgrounds, including students that were new to the Alberta education system or who had gaps in their educational experience, some of her students lacked the same level of background information other students in the class had received through their education. As a result, Ms. T suggested it was the classroom experience that could equalize these differences in base knowledge.

Skills and process. The transfer of science information to post-high school pursuits that are scientific in nature, such as post-secondary studies or “general life skills”, were important components of Ms. T’s definition of scientific literacy. Because her background was in life sciences, Ms. T believed students needed to be able to assess health information such as cancer research, or understand television programming related to health and wellness. She said the students should look to where their life experiences were taking them and “apply” their understanding of science to these new situations. Ms. T spoke of higher level cognitive tasks such as “analysis, evaluation,” integration, and synthesis of information as major components of scientific literacy. Ms. T also believed the day-to-day integration of “general reading comprehension” was an important skill of the scientifically literate.

Attitude. In describing the characteristics of someone who was scientifically literate, Ms. T included both skills based dimensions as well as attitudinal dimensions. To Ms. T, the scientifically literate student was curious and had a high level of interest in the topic. Dependent on the subject matter at hand and the students’ personal bond with the material, students could feel a high degree of “passion” towards science. Ms. T used the example of the connection a student might feel toward a discussion in class of a disease that may be affecting a member of the student’s family as igniting this passion, curiosity, and level of interest. In describing the characteristics of someone who was scientifically literate, she considered someone who was objective instead of subjective, but still drew on their life experiences and was analytical. They would also be considerate of differing perspectives such as the different ways to solve a problem or different individual viewpoints on a particular topic. This individual was "aware of all the variables involved," presumably in addressing a scientific problem, and could approach this problem from different angles, evaluating the "pros and cons of whatever topic was being discussed".

Mr. K's summary. In this study, Mr. K had the greatest number of years of experience and provided the most robust interview, discussing scientific literacy on a much deeper level than the other participants. His understanding of scientific literacy served as a foundation for the most skills- and process-based interview, although his definition included the building of knowledge and an understanding of historical experiments that had led to conclusions connected to scientific inquiry. Mr. K believed that scientific literacy was a range and that the tasks given to different academic levels built scientific literacy but were different in scope. The students Mr. K was working with came from an academic background and his classroom focus was on science process and skills.

Knowledge. The knowledge dimension did not figure strongly in Mr. K's discussion of scientific literacy. He recognized that "our curriculum measures focus more on knowledge" but he did not identify knowledge outcomes explicitly as a requirement for scientific literacy. Rather, Mr. K saw knowledge outcomes as a scaffold from which to build understanding and develop process skills.

Skills and process. Mr. K supported the concept that scientific literacy was linked to the scientific process of defining problems, developing hypotheses, understanding the role of variables in supporting our hypothesis, and building an understanding based on the evidence. He described this process as something teachers were "supposed to do" but something that students struggled to do, particularly at the Grade 10 level, but even at the end of high school. In his opinion, these expectations and others, relating to the "top of Bloom's taxonomy" were the hardest part of the scientific process. And while Mr. K described it as something we were supposed to do, he also pointed out that the language regarding the scientific process was "well-founded in our curriculum" from Kindergarten to Grade 12 and something most students had experienced throughout their education. In lab work, Mr. K felt it was important to move students away from having to find the right answer to determining if "the evidence [needs to] support you and is it within the parameters of the uncertainties and [if] your data [is] sufficient to allow for that."

The belief that students apply a scientific understanding to political and economic decisions and that science should be at the base of many of these decisions was another element of Mr. K's interpretation of scientific literacy. For students, part of becoming scientifically literate is to value the scientific paradigm and use it to make responsible decisions. Also in this realm is making decisions founded on evidence-based research and supporting one's position with a variety of sources, sources such as "books, the Internet, [and] experts [in that field]." Mr. K described what he did in class and while it focused on the scientific process, he identified other useful skills for students to develop. For example, he stressed the importance of "defining clear questions" and during evidence collection comparing data with competing pieces of evidence and evaluating the information, or comparing evidence and opinion and knowing how to reconcile the difference(s).

Mr. K suggested that while knowledge outcomes were figured prominently in the program of studies, they were peripheral to the scientific process. Mr. K built on existing knowledge and scaffolded learning so students had the background they needed when it came to the process component. He saw knowledge outcomes as "far more easy for kids to learn" and be evaluated than process skills and that students knew the what of a concept but not the how. And with current standardized assessment methods, particularly at the Grade 12 level, process skills are difficult to assess in a test format. In Mr. K's opinion, current assessments tested "terminology, the ability to identify elements in the process and the variables and whatnot," but not the entire process (entire program of studies), it's hard to test. He believed it was important to test that part of the curriculum and recognized questions on the diploma exam were working to assess this. However, Mr. K suggested that students be evaluated by practical tasks in class, such as lab work, acknowledging that in some school settings he was familiar that lab activities did not occur, despite being part of the curriculum. With this in mind Mr. K asked, "how do you explore scientific processes and skills without labs?"

Attitude. From an affective standpoint, Mr. K identified that the scientifically literate, as supporters of an "evidence-based philosophy," be skeptical and have a "good understanding of scientific thinking." He recognized an interest in science being linked to scientific literacy although he was uncertain if you became more literate because you were interested in science or because you were more interested in science you became more literate—the idea that science is innate. Finally, valuing and appreciating science, such as the history of science, formed another component of the attitudinal dimension of Mr. K's understanding of scientific literacy.

A summary of all participant statements regarding their understanding of literacy can be found in Appendix D.

Summary of the Data

Once all the transcripts were analyzed, there were 162 phrases related to scientific literacy made by the participants. As identified previously, these statements were coded into one of three categories. Table 7 below shows the distribution of these statements across the three themes.

Table 7

Summary of Statements by Theme

Total Number of Statements by Theme			
	Knowledge 43/162 (26.5%)	Skills and Process 78/162 (48.1%)	Attitude 41/162 (25.3%)
Participant	**Knowledge**	**Skills and Process**	**Attitude**
Mr. V	43.1%	39.1%	17.4%
Ms. S	20.8%	54.2%	25%
Mr. P	14.3%	64.3%	21.4%
Mr. S	11.4%	51.4%	37.1%
Ms. G	42.1%	15.8%	42.1%
Ms. T	31.3%	43.8%	25%
Ms. H	47.7%	40%	13.3%
Mr. K	12.5%	81.3%	6.25%

Participants made more statements about process and skills than statements about knowledge and the attitude. The proportion of knowledge and attitude statements were similar. Individual statements within each category were analyzed to determine which elements in the category were identified most in the teachers' understandings of scientific literacy. A summary of these comments are shown in Table 8 and are referred to as the table of subthemes. To determine this, the number of statements in each broad category, for example knowledge with 43 statements, had 12 comments that related to vocabulary. The percentage total is given in the table at 27.9%. This process was repeated for all statements in each category. In brackets, are the number of participants out of eight that made that statement. The recording of individual teachers' values was done to account for the participants that had a lot to say regarding a particular topic.

Table 8

Summary of Sub-themes

Knowledge	% of statements	Skills and Process Statements	% of statements	Attitude Statements	% of statements
Broad conceptual knowledge	30% (5)	Problem-solving, reasoning and argumentation	21.8% (4)	Shares values of scientists; curiosity, open-minded, skeptical	46.3% (7)
Vocabulary	27.9% (4)	Uses science in everyday life	20.5% (8)	Appreciates science and is interested in science	39.0% (6)
Basic knowledge	20.9% (4)	Uses scientific method	19.2% (6)	Motivated to learn more/interested in keeping up to date	14.6% (2)
Knowledge of laws, theories, models	9.3% (3)	Applies scientific understanding to new contexts	19.2% (7)		
Awareness of science related issues	7.0% (3)	Communicates scientific information	10.3% (4)		
Link between science and other disciplines	4.6% (2)	Integrates knowledge	6.4% (4)		
		Self-learns science	2.6% (1)		

Research Question Two:

What, if any, barriers exist in the implementation of scientific literacy?

The second research question sought to identify barriers perceived by teachers in the implementation of scientific literacy in their classrooms. In analyzing the data, three major areas arose: curricular barriers, teacher related barriers, and student related barriers. All participants identified items in the student-related barrier category while only three teachers identified issues with the curriculum and five identified teacher-related issues.

Student related barriers. When it came to the successful implementation of scientific literacy in the classroom, all participants identified at least one issue relating to the students. Ms. H, whose teaching context included a large ELL population, identified language barriers and a strong understanding of the English language as a barrier to building literacy skills in her classroom. She felt that "communicating using proper language" and their interpretations of class materials would give her an indication of their level of understanding and thus scientific literacy. Communication is consistent with her definition of scientific literacy which emphasized the ability to "understand and communicate scientific topics using proper vocabulary" and so the inability to communicate presented a challenge when it came to scientific literacy.

Ms. G also considered student understanding of language to be a barrier to scientific literacy. While Ms. G's teaching context was not an ELL school, she felt the language skills and basic literacy skills of her students were lacking. She felt that standardized testing at the culmination of a student's studies had become literacy exams that had become more focused on the student's ability to comprehend questions in addition to the scientific principles. She suggested that because of this, some students could "take the science pieces out of it [the question] and relate it." Other students, however, could not see past [the language of the question] and were negatively impacted in terms of their success on the exam. In Ms. G's teaching context, the school-wide emphasis was on traditional literacy skills which she felt included scientific literacy and numeracy as well. Ms. G's definition of scientific literacy was broadly based on literacy itself.

Another teacher from a school with a large ELL population identified student background knowledge as a barrier to scientific literacy. Ms. T included a lack of background knowledge for any student as a barrier but placed a special emphasis and extra challenge on students who had lived in Canada for a short time. Ms. T's understanding of scientific literacy emphasized a strong background understanding of scientific concepts so she suggested that students who lacked this knowledge may be challenged in developing scientific literacy. Student background also presented a challenge to Ms. S. Her reference was not specific to knowledge but to the experiences students brought with them to the class and the variety of learners present in a classroom. She felt these diverse students, particularly when there were many of them in a single class, made it difficult to develop scientific literacy as she understood it. Her definition of scientific literacy included a "foundational knowledge," "understanding of laws and principles," and the application of this understanding to new situations and did not directly tie this to the background understanding of her students.

Mr. V also believed that a "functional knowledge of science vocabulary and the skills and the ability to apply them in a variety of settings" constituted scientific literacy and he saw getting "caught up in the memorization of the fine details" as a barrier to this. In considering Mr. V's entire interview, I believe he meant that students concentrated on the memorization of fine details without seeing the bigger picture and that by focusing on this minutia, students were taking away from their overall understanding of science. Likewise, Mr. P identified student mastery of content outcomes but a lack of understanding of the bigger picture as a barrier.

Participants identified student attitude as playing a part in the development of scientific literacy and that student attitude could act as an obstacle to its acquisition. Mr. S noted that "sometimes when students come to high school they are already turned off science by the time they get to Grade 10." He suggested this lack of interest in science and lack of motivation may stem from a lack of confidence in areas of science. Without motivation, Mr. S suggested it may be difficult to build literacy, and likened it to the inability to read, write, or spell in a humanities course making it difficult to be engaged in writing tasks. Ms. S also saw the "don't like science" mindset as a barrier to engagement and building scientific literacy.

Finally, both Mr. P and Mr. K saw a developmental barrier when it came to scientific literacy. Mr. P described scientific literacy as a developmental process that occurred over time. As a barrier, Mr. P stated that while this took time to develop, not all students have developed it by the time they left high school. Mr. K also suggested that a lack of higher level understanding was a barrier, meaning that students could learn scientific content but could not explain how "they know" a particular concept. Mr. K's definition of scientific literacy included a very small knowledge component stating it was more than memorizing content. He repeatedly mentioned that students needed to be able to scaffold their understanding and explain "how" they knew something to be, focusing on higher level thinking.

When considering student-related barriers, teachers presented a variety of different challenges but little consensus. There was some overlap such as language acquisition, student attitude, and cognitive development, but little consistency among the eight participants as to one significant barrier related to students that interfered with their scientific literacy. As with other findings from this study, the context in which the teacher taught presented unique challenges and perhaps that is why there was little consensus.

Teacher related barriers. Barriers related to teachers were also identified as an impediment to scientific literacy development. Like the student barriers before, many of these barriers were specific to the participant's teaching context. Mr. P's school had recently implemented a flex block, a block of time several times a week that was not part of instructional time. This additional time took away from instructional minutes and gave teachers "less time and more pressure" when it came to addressing content objectives, let alone aspects of scientific literacy. Mr. P also felt that some of the extra tasks associated with the job, such as administrative tasks and developing one's skills regarding technology, took away time that could be spent developing scientific literacy tasks or materials. And while these demands of time stretched Mr. P, when it came to providing the kind of scientific literacy instruction he would like, he acknowledged that he spent three days at the beginning of every term addressing scientific literacy. This came at the expense of content objectives because Mr. P felt it was necessary. Ms. S also felt the burdened by a lack of time. She felt that these constraints prevented teachers from taking students on a "whole new adventure" that would build a deeper level of scientific understanding.

Ms. S felt a challenge that existed, though not the case in her classroom, was that teachers were not preparing engaging materials that would help "flip the switch" for students and develop their interest in scientific matters. She felt that teachers engaged in the curricular materials differently and some were only willing to cover the basics in a very "procedural, information sharing way" that she believed disengaged students and was not motivating. These statements reflected her understanding of scientific literacy and how teachers interpreted the program of studies. She recognized that while the curriculum was a standardized document, the manner in which a teacher interpreted it and what the teacher identified as significant might differ from class to class and school to school. This variance was consistent with the data in research question one that teachers' individual understandings of scientific literacy are shaped by their teaching contexts.

Likewise, Ms. G, who identified a school focus on general literacy in her particular context, felt that a personal challenge for her was not feeling prepared to teach literacy. Ms. G's understanding focused more on the vocabulary, reading, and writing aspects of scientific literacy and as a teacher who specialized in math and science she felt her teacher training did little to prepare her for this type of instruction. While this example was specific to reading and writing, other teachers in the group, such as Ms. T, made statements that suggested they did not feel adequately trained to address scientific literacy. Ms. T indicated she panicked as we began the initial interview because she was not exactly sure what scientific literacy was. As the interview progressed, it was clear that she did have an understanding of literacy but perhaps lacked confidence regarding its delivery.

Not all participants identified teacher-related barriers to scientific literacy, but those who did provided several unique contexts. Additional time demands inside and outside the classroom, teachers' interpretation of the curriculum, and teacher confidence regarding the understanding of scientific literacy all factored into this barrier of scientific literacy development.

Curricular barriers. The final barrier group as identified by three of the participants was related to the curriculum. This barrier was more than just the volume of the curriculum in terms of content objectives, but also, as Ms. S stated, the choice of topics and placement in the program of studies. She spoke of taking the students in different directions based on their interests and abilities but feeling bound by the curriculum. Further to this, she suggested that perhaps a different curricular model would allow teachers to take student learning in a different direction and might even maintain student motivation, but she was uncertain what this model would look like. Ms. S did note that the curriculum did serve a vital function in maintaining a certain breadth of knowledge and part of her definition included this basic scientific understanding.

Mr. K suggested the challenges with scientific literacy in the curriculum are two-fold: one, scientific literacy was not evaluated in a formal sense at the end of Grade 12, and two, the scientific literacy framework in the curriculum was a goal with curricular suggestions to meet this goal that were not all mandatory. Because of this, Mr. K suggested that teachers did not feel the same degree of pressure to address these aspects of the curriculum such as content objectives which were evaluated in formal examinations. It is worth noting that these culminating exams are only written at the Grade 12 level, but evidently teachers feel significant pressure to scaffold the content knowledge throughout the students' high school career. Despite these statements, Mr. K did not necessarily identify with these barriers but added that scientific literacy was important for students because content knowledge may fade over time but scientific literacy in the form of process skills could be with the student throughout their life.

Looking beyond just the science curriculum, Mr. S felt that a barrier was the science component of a general high school diploma. In comparison to other subjects like English and Social Studies, two science courses are required to graduate from high school with a general diploma. Mr. S suggested that science education was not valued in the province of Alberta as some other subjects and that graduation requirements should require more science courses. By doing more to encourage science education, Mr. S thought more students might be motivated to take it and this might help build scientific literacy.

There were 31 barrier-related statements made by the teachers. Of the barriers identified, half were student related. The remaining barriers were made up of teacher-related and curriculum-related. Table 9 summarizes the barriers to scientific literacy as identified by this sample of teachers.

Table 9

Summary of Barriers to Scientific Literacy with examples

Student Related Barriers 15/31(50%)	**Teacher Related Barriers 10/31(30%)**	**Curriculum Related Barriers 6/31(20%)**
Students come from different backgrounds and have different levels of prerequisite understanding	Time consuming and takes away from content areas	Large number of topics, placement of topics
Attitude of not liking science	Other classroom challenges beyond curriculum	Science education not valued
Inclination to focus on memorization of details	Not feeling prepared or lack knowledge to teach scientific literacy	General diploma should have greater science requirement
Students can learn content but are unable to see big picture	How to prepare materials that inspire students (Flip the switch)	Scientific literacy not evaluated and not mandatory

Are students scientifically literate? One other element that came out of the barriers discussion was determining if students were scientifically literate at the end of their K-12 education. The views of the participants were that students had some degree of scientific literacy at the end of their schooling, with only one individual indicating this was not the case. What was more interesting were the reasons why some individuals became more scientifically literate than others. While the reasons for scientific literacy are diverse, some of them point to factors that are not something that can be directly taught. For example, both Mr. K and Ms. G stated that students with an interest in science may be more literate than others, or as Ms. T notes, often student curiosity is related to scientific literacy. At the extremes, Mr. V believed students had a basic level of scientific literacy, while Ms. T believed students were not literate although she did not elaborate on why this was the case. Mr. S was also uncertain if students were literate but hoped that this was the case. Mr. K and Ms. H believed there was a range of scientific literacy among students, and Ms. H felt she had given her students the tools required to be scientifically literate adults.

Conclusion

All teachers identified scientific literacy as an important goal for science education. When considering individual components of scientific literacy, just over 50% of teachers ranked process and skills as the key component of their understanding of scientific literacy, while knowledge and attitudinal dimensions were almost equal seconds. Much of what the teachers emphasized was based on the context they taught in and was specific to their learning environment. While teachers ranked process and skills more frequently, there were a variety of topics within this category and many variation of teacher views. All teachers felt that barriers existed that impeded their implementation of scientific literacy instruction. While these barriers were varied, they fell into three general categories: student-related barriers, teacher-related barriers, and curriculum-related barriers. Student-related barriers were identified most frequently, with 50% of the statements regarding barriers falling into this category. Further, every participant reported at least one student-related barrier. Teacher and curricular barriers made up the remaining 50% of barriers identified, with five participants identifying teacher-related barriers and three identifying curricular barriers.

Chapter 5
Discussion

Introduction

In this chapter I will discuss how the participants of this study describe scientific literacy and identify areas of consensus and areas of divergence, as well as perceived barriers. Limitations of this study, future research, and personal thoughts will conclude this section.

The purpose of this study was to investigate secondary school teachers' understandings of the scientific literacy component of the high school science program of studies. Secondly, teachers were asked to identify what barriers, if any, they faced in the development of scientific literacy. The intention of this work was to determine if high school teachers shared a common understanding of scientific literacy or if differences existed. Data for this study came from eight teachers to generate their understanding of scientific literacy. Due to the small size of this sample, I would not suggest the findings here reflect an understanding shared by all Alberta secondary science teachers. Each participant was interviewed in a face-to-face session that utilized a semi-structured questioning format. This structure allowed other questions to develop from the interview. From this, I found that all participant teachers believed scientific literacy was important, and each worked to develop it in their students, though not all thought students were scientifically literate at the end of high school. The teachers' understandings included knowledge, skills, and processes and attitudinal elements but each teacher had emphasized different subthemes. The second question established that teachers did identify barriers which influenced the development of scientific literacy.

Discussion

Scientific literacy has long been considered a goal of science education and it is considered by many to be THE goal. Since the term was first used, 60 years ago, the definition of the term has evolved with the changing societal needs and has come to encompass many things. Within the literature there has been a lack of consensus in defining scientific literacy and whether it is an attainable and necessary goal for education. Many educational documents now apply a comprehensive definition to scientific literacy that addresses many points, including content and knowledge objectives, scientific skills and processes, as well as attitude. In Alberta, knowledge, skills, and attitudes are developed in working towards a goal of scientific literacy.

Minimal research has been done to suggest a uniform definition is necessary for effective instruction of scientific literacy. Salomon writes that while there is no consensus on the definition of scientific literacy, there is agreement that it is important (2007).

In considering teachers' understanding, I am indirectly questioning whether or not there needs to be a consensus in the definition for it to be useful in science education. Kemp (2002) was concerned that with the many definitions of scientific literacy, educators may believe they are working towards a common goal (based on their understanding) when in fact they are not. He suggested that there may be educational repercussions when these understandings differ, such as a lack of direction in the curriculum or teachers not knowing what to teach. In the same paper, however, Kemp states that some researchers believe a uniform definition may be limiting and leave educators lacking the flexibility to accommodate differences in teaching context. Laugksch (1999) has suggested this may be the case, arguing it is impractical to have a common understanding given the different teaching contexts. In Kemp's study, several participants credit national standards publications to contributing to a greater consensus regarding scientific literacy, though Kemp concludes there is still too great of disparity in views to be useful.

Many of the definitions commonly used in education circles focus on knowledge elements, nature of science elements, and relating science to society (Solomon, 2007). Using a broad approach allows for some elements of consensus and some flexibility. In this study, each participant emphasized different subthemes of scientific literacy but shared the end goal of scientifically literate students, and they seem to have a similar conception of a scientifically literate individual. At the beginning of this research, I would have sided with Kemp's uniform definition of scientific literacy; teachers should all have a standard definition so it could be ensured that the goal of scientific literacy was met, assuming that students were scientifically literate at the end of high school. At the end of my work, though, I see the benefit of a varied definition with some shared elements, but ultimately left for teacher interpretation based on their teaching context. I see the dynamic nature of scientific literacy and the realization that scientific literacy is a lifelong pursuit that does not end with high school. This is what I observed with the participants; they all identified multiple concepts in their understanding, but their emphasis was dependent on the context in which they taught. As an example, Ms. H identified knowledge, skill, and attitude elements in her definition, but because of the ELL aspect of her teaching context she focused on knowledge elements such as vocabulary and terminology.

Summary of Findings

The data was organized into three categories to identify different understandings of scientific literacy. These groups—knowledge, skills and process, and attitude—were modeled after the Alberta science program of studies and loosely after Kemp's categorization of conceptual, procedural, and affective dimensions of scientific literacy. Alberta teachers constructed their understandings with elements from each category, but favored certain elements more than others, much like Kemp's participants. In this sample of teachers, skills and processes were identified by 63% of teachers as the dominant component of scientific literacy. The research of Stock (2010) indicated that teachers valued skills and processes over knowledge in their teaching and Haury (1993) states that instruction that uses scientific inquiry can have a positive impact on scientific literacy. The participants next identified knowledge outcomes, which include conceptual knowledge as an important part of their understanding. This ranking of knowledge second was unexpected. School science has been founded on the mastery of concepts (Miller 2010), and Stock (2010) noted that teachers spent more time on knowledge and content outcomes, so it was surprising that more teachers did not rank this understanding above skills and process. Finally, attitudinal understandings were ranked third, but their ranking was almost equal to that of knowledge.

Research Question One:

How do Alberta Secondary Science Teachers Understand Scientific Literacy?

Areas of consensus.

All of the participants in this study felt scientific literacy was an important goal for science education and something that was beneficial for society. This view was something I expected to find as scientific literacy was a goal of science education in Alberta and many science programs. When considering the understandings of scientific literacy, all participants included knowledge components, skills, and processes as well as attitude (KSPA). I do not know if this is due to the way the Alberta science program of studies is formatted, as it is formatted with KSPA objectives, or if teachers would have identified these elements regardless.

The knowledge understanding included subthemes related to conceptual knowledge of science. In the knowledge category, the teachers most frequently identified the subthemes of broad conceptual knowledge, basic understanding of concepts, and science vocabulary. Within the skills and process understanding was the application of scientific understanding and elements associated with scientific processes. The dominant understandings in this area were "uses science in everyday life" such as taking a position regarding climate change or "applies scientific understanding" such as reading a science-based newspaper article and being able to understand the science in it. These two areas may have been collectively called everyday coping in other literature by Roberts (2007), but were separated in this study to determine which element had greater emphasis. The identification of these types of skills in scientific literacy was not unexpected as this type of application of understanding is in many scientific literacy documents. Finally, attitude was an understanding that included shared values of scientists, such as skepticism, as well as interest in science and motivation to learn more. These attitudes formed foundational aspects of the Alberta Science Program of Studies such as appreciation of different perspectives, and these outcomes work in conjunction with knowledge and skill outcomes (Alberta Learning, 2014). It would seem that while all teachers did not acknowledge their familiarity with the concept of scientific literacy, they did have an understanding of the curricular expectations.

While each of the participants included elements of knowledge, skills and process, and attitude in their understanding, most teachers favored one understanding more than the others. Looking at the individual responses in each of the KSPA categories resulted in some fairly broad understandings and others that were relatively narrow in scope. For example, Mr. S and Ms. S both included 12 of the 16 subthemes in their definitions, while Mr. P only included six. Mr. P focused mostly on skills and processes, while Mr. S and Ms. S included a variety of responses from each category.

In the knowledge category, there was not consensus as to which was the dominant subtheme of scientific literacy. The broad and basic understandings were mentioned by five and four participants respectively. A broad understanding represented the understanding of many topics in science, while a basic understanding addressed the level of comprehension required. Three participants stated that a broad exposure to topics helped students from getting bogged down in the details and allowed them to understand the overarching themes of science. This knowledge base created a basic scaffold from which additional knowledge could be built. The Alberta curricular documents do have an extensive content component, covering a wide variety of topics. Broad content knowledge is seen in other educational documents as well. In the PISA 2015 draft (PISA, 2013), students were required to have content knowledge to build upon other types of scientific literacy components, content knowledge that included "an understanding of the major facts, concepts and explanatory theories that form the basis of scientific knowledge" (p. 31). Half of the participants in this study included the vocabulary of science, but their reasons for doing so varied greatly. Some focused on vocabulary from an ELL perspective and others suggested that having a strong knowledge of vocabulary could help students understand science concepts.

Skills and processes ranked the highest of the three understandings by more than half of the participants. These elements represent the takeaways of science—some of the practical ways students could use science beyond high school. In this category, all participants believed "uses science in everyday life" was an important component of scientific literacy. Statements surrounding science in everyday life pertained to teacher comments regarding decision making and the civil and political applications of science. The NSTA (1990) and AAAS (1993) state that the use of science in everyday life should be one of the goals of science education and Kemp (2002) found that the majority of his participants also identified science in everyday life as a goal. The theme of making decisions related to policy and using science information in our understanding permeates much of the literature relating to citizen science; (Lee & Roth, 2003). Similar to this was "applies scientific understanding to new contexts." Using science in this way may allow one to make sense out of newspaper article or interpret health information. Both "uses science in everyday life" and "applies science understanding" are similar to Robert's concept of everyday coping which uses science to understand one's environment (2007). The research of Stock (2010) and Chu (2012) showed that everyday coping was a significant element of science education, with Stock's research participants identifying it as the ultimate end product of science education. Given its frequent presence in the literature, the identification of these types of skills in scientific literacy was not unexpected.

Finally, all participants indicated the values shared by scientists were a part of their attitude understanding. The values include curiosity, open-mindedness, and skepticism. Participants described how scientists and students should consider different perspectives and solutions, be objective, ask questions, not jump to conclusions, and above all be curious. Many of these elements fall under the habits of mind umbrella. Project 2061 (1993) lists several of these shared attitudes such being curious, open to new ideas, and skeptical. The goals of Project 2061 also include enjoying science and science is open to improvement which represents important science attitudes.

Areas of discrepancy.

This research showed some discrepancies from other research findings. In the research of Kemp (2002), the participants usually included elements of communication in their definition of scientific literacy, such as reading, writing or speaking. In this study, however, only half of the participants identified "communication" as part of their understanding, focusing on primarily on reading and to a lesser extent on verbal and written communication. Norris and Phillips (2002) define fundamental literacy as reading and writing when the content is science, which seemed to be what was being described by the teachers in this context, specifically reading science magazines. One participant identified "wants to learn more" as an attitude of the scientifically literate, yet researchers, such as Koballa et al. (1997) or DeBoer (2000) have suggested that continuing to learn about science is important for improving scientific literacy. Few participants identified knowledge of the theories and laws as significant elements of scientific literacy, though two participants included it in a definition of scientific literacy. The exclusion of laws and theories was unexpected, as observing phenomenon to generalize theories and supporting these theories through observation has become the backbone of science Holbrook and Rannikmae (2007). The Alberta Science Program of Studies (Alberta Education, 2014) describe the link between science and other disciplines as a key foundation for science learning and the link between science and technology has been described by DeBoer (2000), as an element of scientific literacy, yet this was rarely mentioned by participants. One participant described the link between one science (chemistry) and the other sciences as supporting the development of scientific literacy, and the other participant described students' reluctance to use science understanding in other contexts. The lack of discussion regarding links suggests that maybe science teachers still adopt a discipline-bound approach to science when the field of science is becoming more holistic and adopting transdisciplinary or cross-disciplinary approaches (Hurd, 1998). The remaining responses regarding the subthemes of scientific literacy are more contextually based. As I have already suggested, my belief is that many of the differences in definition come from the individual teaching context, and it is possible their understanding of scientific literacy may be fluid, depending on context. Kemp's (2002) participants suggested this might be the case and definitions of scientific literacy may change over time and place.

Research Question Two: Do Barriers Exist that Impede the Development of Scientific Literacy?

Areas of consensus.

In this study, all participants felt barriers existed that influenced the development of scientific literacy. After assessing all statements, the barriers were divided into three categories; student-related, teacher-related, and curriculum-related. Student-related categories were wide-ranging and included challenges related to learning, application of science, motivation, and interest in science. The teacher-related challenges were related to teacher responsibilities outside the classroom and the impact of these on instruction, time constraints of the school timetable, and teacher training and comfort with both literacy and scientific literacy. The least identified barrier was related to the curriculum (i.e., a means to assess scientific literacy and the structure of the curriculum) (what was to be taught, the sequence of topics). Of these categories, only student-related barriers had responses from all eight participants. The barriers identified by teachers often corresponded with the elements identified in their understanding of scientific literacy. For example, one participant stated lack of motivation was a barrier to scientific literacy but indicated that students develop scientific literacy by being motivated to learn more about science.

Areas of discrepancy.

There was minimal consensus regarding which barriers impacted scientific literacy development and those identified were based on the specific teaching context. For example, student background was identified as a barrier by teachers in this study, but these background challenges varied by teaching context. Two of the teachers talked extensively about their students' ELL experiences and the challenges these presented. Lee and Fradd (1998) reinforce this notion that for students learning English, as well as science, additional challenges are present. In considering the remaining student challenges of not liking science, not seeing the bigger picture, and a focus on memorization, these are probably not challenges limited to science literacy education. When measuring attitudes towards scientific literacy Holden (2012) found that there was little difference between science and non-science students, but a UNESCO (2000) survey found that science learning is harder than other subjects and students may be disinterested because it is irrelevant to their lives. Irrelevant science was contrary to what participants said about how they taught and how they wished to make scientific literacy relevant to the students' lives. Singh, Granville, and Dika (2002) report that student motivation, attitude, and interest are related to achievement, and these factors are related to both external factors such as parent and peer influences as well as internal factors such as engagement. While they also suggest that by high school students have already determined if they will continue to pursue science, schools can do their part by targeting the engagement element. Because there was little consensus on individual points and they were often specific to teaching context, it is difficult to make any claims about the impact of barriers on scientific literacy development other than to note they are a concern among teachers.

Teachers also had varying opinions as to whether students were scientifically literate at the end of high school education. Some individuals believed students were while others were not, some saw scientific literacy as a continuum with students falling at various points. The continuum approach is likely the most realistic scenario and supported by Koballa et al. (1999). At the beginning of this research, I had expected more teachers to indicate that students were scientifically literate and were being sent into the world with the foundational basics to navigate the world. I now recognize this was an unrealistic goal and the role of schooling as Miller (2010) writes, is to build this foundation, with most people developing their scientific literacy as adults, beyond school.

Conclusions

Based on the teachers in this sample, science teachers in Alberta have a firm understanding of scientific literacy. When describing scientific literacy they include knowledge, process and skills, as well as attitude. These fit the definition of scientific literacy dictated by the Alberta Science Program of Studies. The teachers were fairly diverse in the individual elements of each category but adopted this approach to match the requirements of the students in their teaching context. I suspect teachers assume a general approach because much of the educational documents take a broad stance with flexibility for individual interpretation and professional judgment. Teachers identified a variety of barriers to the development of scientific literacy, including student-related, teacher-related, and curricular barriers, and there was little consensus among the participants. Like their understandings of scientific literacy, these barriers were often the result of the teaching context and were not universally applicable.

Limitations

At the completion of this project, I have identified several limitations to the project design. Access to participants and the number of participants proved to be the greatest limitations to this study. Recruitment difficulty was due in part to the timing of participation requests, as well as the manner in which participants were recruited. The sample size of eight individuals was smaller than I would have liked. I do not believe I reached data saturation, and a few more participants could have provided more insights.

A second limitation was the use of "backyard" research as described by Glesne and Peshkin in Creswell (2009) where one studies individuals associated with one's work setting. More than one of the study participants was known to the researcher, but care was taken not to allow this relationship to impede the validity of the data collected. Additionally, the researcher was not in a position of authority over any participants, so there was no concern of data compromise in this regard.

Finally, I was not able to see what the teachers did in their classrooms and if their practice reflected their understanding of scientific literacy. Tsai (2002) and Brickhouse (1990) have studied how teacher beliefs regarding science are often reflected in the way they teach. One might expect teachers' understandings of scientific literacy to be reflected in their teaching but without observation one cannot be certain. The participants' descriptions of how they taught seemed to suggest this was the case, but as Stock (2010) documented, sometimes what teachers believe is important is not evident in their teaching.

Future Research

Now that the major categories for understanding scientific literacy among Alberta teachers have been identified in this study, an interesting follow-up might be a quantitative study of a larger group of teachers in Alberta. Using a survey instrument may allow the views of teachers in other parts of the province to be examined in a more accessible manner than face-to-face interviews and allow for a more robust sample of understandings of scientific literacy in this province. I also believe extending this investigation to include Junior High teachers may have provided a richer data source. They have the same program rationale and philosophy in their program of studies and therefore the same opportunity to develop scientific literacy. Finally, it would be valuable to observe teachers in their classrooms to determine if their instructional mode of scientific literacy was compatible with their understanding of scientific literacy.

Personal Thoughts

Scientific literacy is a complex topic due, in large part, to its many definitions. As I set out to research teachers' understandings of this subject I was concerned that teachers were somehow missing this part of the curriculum. The interview process assured me they were not, and like so many things in education, teachers were adapting a particular part of the curriculum to suit their students' needs and teaching environment. All participants acknowledged that their instruction included knowledge, skill and process, and attitudinal components of scientific literacy but that they chose to focus on the components that fit their personal teaching context. I now recognize the definition of scientific literacy can shift over time and context and having a broad-based curricular document can support this topic. Teachers' understanding of scientific literacy is no different to how any element of the program of studies is interpreted. It is the role of the teacher as a professional to utilize the curriculum to help educate students, and I have less concern that an exact definition is shared when the basic elements of knowledge, process and skills, and attitude are the same.

It would seem that the definition of scientific literacy in the Alberta Program of Studies is working for most teachers and perhaps the focus in support of this educational element should be on addressing the barriers of teaching it. Many of the barriers were tied to the teaching context and were not consistent among teachers. I believe many of the barriers identified in this study are experienced by teachers across both grade levels and subject matter and are not unique to scientific literacy. I also came to realize that many of the themes in scientific literacy are not unique to science at all. One of the participants, Mr. K, brought up how much of what we do as science teachers are similar to that of English or Social Studies teachers, or even Math. Across disciplines we analyze, evaluate, use evidence to support our arguments, or use a specialized language to support our subject. Maybe it would be more useful to recognize that each discipline is not unique and in this way have supports in place across disciplines. Mr. K talked about other ways of knowing and that science was just one way of knowing. This shared understanding may then create an environment to allow engagement in more cross-subject conversations with colleagues.

Scientific literacy has been described as a lifelong skill and something students and, in fact, all people need the opportunity to use to become proficient in science and maintain proficiency (Cobern, 1995; Koballa et al., 1999). Others, like Shamos, (1990) disagree believing that only scientists are scientifically literate and pursuing scientific literacy is a futile endeavor. Still others, like one of Kemp's participants, asked why scientific literacy was important for K-12 students when adults seemed to navigate the world fine. Kemps participant suggested reconsidering scientific literacy less as a goal for education and possibly focusing more on science awareness. I would argue that because of the scientific and technical world we live in, our work as science teachers is necessary to build a foundation so adults can navigate the world and function properly as citizens. Most of the general public can cope in society without knowing the intricacies of Quantum physics, but in our conversations, interactions in society, and media consumption a basic understanding of science and the scientific process is necessary. My hope is that this project will contribute to discussions of future science curricula, will give participant teachers an opportunity for reflection of scientific literacy in the classroom, and may encourage future research in a field that has spanned science teaching for over 50 years.

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Appendix A

Semi-structured Interview Questions

Based on the interview questions of Andrew Kemp

1. Scientific literacy has been characterized as a fundamental goal of science education both locally in Alberta and the rest of the world. Do you agree or disagree? Please explain your response.
2. Why is scientific literacy necessary or beneficial for an individual in Alberta/Canada? (Or for society?)
3. Think of someone you know who is scientifically literate. Describe the characteristics of that person that makes them scientifically literate.
4. Do you consider yourself to be scientifically literate? What characteristics do you have that make you scientifically literate?
5. Considering your own students, how do you develop scientific literacy?
6. How or why do some individuals become more scientifically literate than others?
7. Do you consider your students to be scientifically literate at the end of their high school education?
8. In your teaching experience what challenges have you faced in the development of scientific literacy in your classroom?
9. What evidence do you have that scientific literacy has been developed?
10. Is there anything else you can think of that you would like to share about scientific literacy?

Appendix B

Information Letter and Teacher Consent Form:

Alberta Secondary Science Teachers' Definitions of Scientific Literacy

Dear Science Teacher,

As part of my thesis work at the University of Alberta, I am currently conducting a research study that explores science teachers' views of scientific literacy and how they develop scientific literacy in their students.The results of this study will be used in support of my thesis work, and may be used for publication at a later date.

The purpose of this research is to gain insight into teacher interpretations of the scientific literacy outcomes of the Secondary Science Program of studies, as well as how teachers implement these outcomes in their classrooms.

Should you agree to participate in this research, the total time requirement from you will be approximately 1.5 hours over a one week period. During our meeting, you will be asked a series of interview questions over a 30-60 minute period of time. This meeting will take place in a private location of your choice, such as your own home or a room that I book at the University of Alberta, or through online supports such as Skype. During this interview, I will ask a series of questions designed to categorize your personal definition of scientific literacy. This interview will be recorded to allow a digital record of our interview. Following the interview, I will forward transcripts from our meeting and you will be given the opportunity to review, correct, clarify or omit the data you presented during our interview. This review process should take no more than 30 minutes and you may contact me by phone or email to makes any changes to your data.

There are no major risks associated with you being involved in this study. As a result of participating in this research, you may become more aware of your attitudes and approaches to scientific literacy in the classroom. This may also help you consider how you develop scientific literacy skills in your classroom. I believe the information gathered from this study may help inform curricular planners and teacher educators to develop programming that ensures consistencies in scientific literacy programming.

Voluntary Participation

Your participation in this study is entirely voluntary. Should you choose to participate in the study, you are under no obligation to answer any specific interview questions. Even if you agree to be in the study, you can change your mind and end your participation at any time. If you end your involvement in the study early, I will use previously collected data unless you wish to have it withdrawn. There is no penalty for ending your participation or withdrawing your data from the study. Should you wish to withdraw from the study, you may do so up to two weeks after you are provided the transcript of our interview.

The data from this study will be used in the preparation and defense of my master's thesis and may also be used for future publications in academic journals or presentations at conferences. You will not be personally identified in any of these documents or presentations; a pseudonym will be utilized in the place of your name. My supervisor, Dr. Norma Nocente, will have access to the anonymous data in order to assist me with analysis and provide feedback; she will never be able to identify you as a participant. All data for this study will be kept in a secure place for a minimum of five years following the completion of the research project. Electronic data will be kept in password protected files; hard copies of any data will be kept in a locked filing cabinet. I may use the data I get from this study in future research projects, but if I do this I will obtain approval from a Research Ethics Board.

If you wish to participate in this study, please sign the attached consent form and contact me at heinsen@ualberta.ca or 780-937-5538. If you have any further questions regarding this study, please do not hesitate to contact me or my supervisor at either the email or phone number listed below. The plan for this study has been reviewed for its adherence to ethical guidelines by a Research Ethics Board at the University of Alberta. For questions regarding participant rights and ethical conduct of research, contact the Research Ethics Office at (780) 492-2615.

Thank you for your interest in this research,

Leslie Heinsen
heinsen@ualberta.ca, 780-937-5538

Supervisor:
Dr. Norma Nocente
norma.nocente@ualberta.ca 780-492-3676

Alberta Secondary Science Teachers' Definitions of Scientific Literacy

Name (please print): ____________________________ Date: ____________________

I consent to allow the following data to be used for this project, including its use in Leslie Heinsen's Master's thesis as well as future presentations and publications:

• Audio- recording of interview

I have read and understand the details in the information letter and consent to participate in this

_______________________________________ _________________________________

Signature of Participant Name of Participant

Please keep a copy of the information letter for your records. A copy of your signed consent form will also be provided to you. If you have any questions or concerns about your rights as a participant, or how this study is being conducted, you may contact the Research Ethics Office at 780-492-2615. This office has no affiliation with the study investigators.

Appendix C

Ethic Approval Notification

Notification of Approval

Date:	May 20, 2014
Study ID:	Pro00043050
Principal Investigator:	Leslie Heinsen
Study Supervisor:	Norma Nocente
Study Title:	Teachers' definitions of scientific literacy in Alberta
Approval Expiry Date:	May 19, 2015

Approved Consent Form:	Approval Date	Approved Document
	20/05/2014	Information letter and consent form

Thank you for submitting the above study to the Research Ethics Board 1. Your application has been reviewed and approved on behalf of the committee.

A renewal report must be submitted next year prior to the expiry of this approval if your study still requires ethics approval. If you do not renew on or before the renewal expiry date, you will have to re-submit an ethics application.

Approval by the Research Ethics Board does not encompass authorization to access the staff, students, facilities or resources of local institutions for the purposes of the research.

Sincerely,

William Dunn, PhD
Chair, Research Ethics Board 1

Note: This correspondence includes an electronic signature (validation and approval via an online system).

Appendix D

Summary of Knowledge, Skills and Process and Attitude Dimensions of Scientific Literacy

Participant	**Knowledge Dimension of Scientific Literacy**	**Skills and Process Dimension of Scientific Literacy**	**Attitudinal Dimension of Scientific Literacy**
	The scientifically literate person:		
Mr. V	Understands big concepts, not fine details Basic understanding of concepts Functional knowledge of science vocabulary Connects science to other disciplines and technology Understands language of science	Uses language to understand science in everyday life Understands how science can contribute to the economy Applies science to hands-on activities Uses science to understand media and the world	Open to new ways of thinking Has a problem solving philosophy Willing to listen to others Wants to know more about science Wants to know more Doesn't hate science
Ms. S	Has a baseline of knowledge Basic understanding of high school science Breadth of knowledge, not depth Understands fundamental pieces of information Understands the laws and guiding principles of the universe Has foundational knowledge	Can make personal and societal decisions using science Apply scientific information to new situations Learns to question Engages in hands-on inquiry Understands the scientific process through lab skills Can communicate scientific information through written information Collaborate with others through group talk	Is a critical thinker Is objective and logical Is curious Is a natural inquirer Reflects on scientific questions Delves into their own beliefs

		Has the skills to analyze the world Uses strategies to solve problems	
Mr. P	Can distinguish pseudoscience from science Knows what science is Has some content knowledge Connects sciences	Understands and uses the scientific method Can solve problems Writes hypotheses, presents data and writes conclusions based on experimental evidence Can apply scientific principles to the real world Can draw a conclusion based on open ended problems Sees relationships between variables	Is not afraid to say I don't know Is skeptical Thinks like a scientist Is confident
Mr. S	Has a good understanding of science Understands big ideas Understands the work of scientists Has basic knowledge Knows a lot about different science topics Aware of current trends and discoveries in science	Applies science to everyday life Can apply, synthesize and summarize scientific information Critically examines information Connects science and society Understands ethical issues Uses science to practice good citizenship and make decisions	Has an interest in science Is motivated to learn more about science Has confidence Is passionate about science Is a critical thinker Is confident and is motivated
Ms. G	Has a large vocabulary Comprehends science words	Can related science information to new contexts Asks questions Can read scientific information and understands	Has an appreciation for learning Always wonders

		what they read	Has a love of science Is passionate about science Finds science meaningful Is an inquirer
Ms. H	The scientifically literate person Uses scientific terminology and examples that not everyone would understand Uses proper scientific vocabulary Studies more than one scientific discipline Understands theories and concepts currently accepted by science	Applies science to everyday life including new situations and vocational context Questions how the world works using scientific principles Asks questions Reads scientific literature and can synthesize the information Challenges ideas Communicates scientific information using proper language Interprets scientific information Interprets lab results Communicates understanding Develops new explanations	Is interested in science Pursue topics that are scientific Challenging ideas that have not initially been challenged
Ms. T	Has a base knowledge of scientific information Knows scientific facts and information Has background knowledge Understands the curriculum content Knows basic scientific concepts	Applies scientific understanding as a general life skill or to post-secondary studies Is aware of all the variables involved Approaches problems from various perspectives Evaluates the pros and cons of a situation Can interpret analyze and evaluate information	Is curious Feels passion towards science Considers the perspectives of others Is objective and analytical

		Can integrate and synthesize information Has general reading comprehension	Is interested in science topics
Mr. K	Scaffolds knowledge outcomes Includes some history of science	Uses scientific understanding to evaluate economic and political decisions Can apply scientific information to new situations Defines questions, develops hypotheses, identifies variables, tests hypotheses and reports data Supports information with current research Balances opinion with evidence Compares evidence Practices lab skills and engages in practical work Collaborates with others Engages in scientific inquiry Gathers evidence to support and argument	Good understanding of scientific thinking Adheres to the scientific paradigm Supports evidenced-based philosophies Is interested in science Values and appreciates science